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RECENT INVESTIGATIONS CONCERNING DYNAMICAL ACTION IN SHAFTING OF MARINE ENGINES, WITH SPECIAL REFERENCE TO SYNCHRONOUS TORSIONAL VIBRATIONS.*

BY HERMANN FRAHM, WITH BLOHM & VOSS, HAMBURG.

Marine engineers have for a number of years had to deal with mysterious fractures of shafts taking place during fair weather, and which could not be accounted for by any of the ordinary causes, such as bad material or propellers striking floating bodies.

The peculiar fact that occasionally the lines of fracture of the broken shaft resembled those caused by twisting actions pointed towards the existence of considerable twisting moments, but an explanation as to their origin could not be given. It was out of the question that the steam pressures formed the direct causes

* This forms a more completely-executed theoretical treatment of a paper read before the German Philosophical Society at its last meeting, in September, 1901, at Hamburg.

of this, as their maximum values, determined by the crank-effort diagram, rarely exceed the average value by more than 50 per cent., and would therefore create a twisting stress of, at most, 300 to 350 kilograms per square centimeter, the working stress allowed being about 200 to 230 kilograms per square centimeter.

It then appears that actions of dynamical nature hitherto insufficiently known, combined with other destructive influences, such as corrosion, etc., formed the main cause of the fractures.

Various authorities had already pointed out that possibly the so-called synchronous vibrations took place in the shafting, but this supposition had not been verified by direct researches.

Messrs. Blohm & Voss, of Hamburg, therefore determined, in November, 1899, to study the question experimentally, and I was charged to make the necessary experiments, and to work out the results obtained scientifically. Since then experiments have been regularly carried out on all their trial trips.

Before commencing the description of the experimental plant I intend to mention briefly the points which have to be kept in view. In large steamers the distance between the power-generating engine and the power-absorbing propeller is, as a rule, quite a considerable one. It is therefore obvious that the whole of the shafting, in consequence of its length, must be regarded as a more or less elastic torsional spring, and not as an absolutely rigid body. This "spring" is kept twisted by the turning moment transmitted from the engine to the propeller. If we had to deal with motors possessing constant turning moment, such as electric motors or steam turbines, the whole system, including the propeller, would revolve uniformly, assuming the resistance of the propeller not to vary, the shafting consequently being subject to a constant twisting moment, and hence retaining a constant "twist" throughout the revolution. But the case is different when the turning force is no more constant, but subject to oscillations such as take place necessarily in steam engines with reciprocating pistons. In this case the shafting also will show oscillations of the twisting stress, and consequently of the amount of twist, as well as speed. It must be pointed out, however, that

the first-mentioned oscillations are not at all proportional to the turning forces due to the pistons, as one might be inclined to think, but in magnitude depend upon the mutual relations between the elasticity of shafting and the moving masses in the engine and propeller.

Calculation with a view of fixing this relation beforehand will, however, as we shall presently see, be of a rather complicated and difficult character. The want of knowledge of the relation governing the resistance of a propeller against turning at and during variations of speed, has hitherto prevented a correct calculation of this kind from being made, particularly at the critical speeds, to be considered later. This point, as well as the magnitude of the variations of the twisting stresses, thus formed the chief object of the experiments.

The following points determined the nature of the installations:

First of all, the twisting stresses in the shafting had to be found, both with regard to magnitude and variations, whilst the engine was running. This might be done by determining, at convenient intervals during one complete revolution, the instantaneous "twist" of the shaft, whereby the stress may be calculated. Secondly, in order to complete this information, it would be necessary to determine the corresponding variations of speed of the whole system, taking engine and propeller each by itself.

Preliminary experiments of rather laborious character had to be made in order to find the reliable method, which will be described now.

Thin zinc sheets were attached round the couplings of the shaft in question, as far apart as possible, and easy of access. They had been prepared in a special way for the purpose. Against each of these flanges a fine platinum point was arranged in such a manner that it might be pressed against the zinc sheets by means of a lever, all carried on the nut of a screw which would move it along parallel to the shaft.

At a convenient place in the shaft passage, preferably close to one of these flanges, a small electric motor with speed-regulating gear was arranged, carrying on its spindle two identical contact

discs, which served the purpose of breaking and closing two otherwise independent circuits simultaneously and at equal intervals. These circuits start from the positive terminals of the ship's main switch board, contain suitable resistances, then pass the above-mentioned interrupting discs, go on to the platinum points, and finally, when these touch the zinc sheets, through the latter ones to the negative terminal. The zinc sheets are chemically covered with a conductive black film of oxide, which possesses the property of leaving a white mark where the current has gone through it, whereas the platinum points leave it intact when no current passes.

Figure 1 shows a photo of the after end of the shaft passage in a large steamer, with the experimental gear in place. The flange visible is the aftermost one in the tunnel, and is used for measuring purposes. The other flange in this case was selected directly abaft the thrust bearing, and hence does not appear in the picture. On the table in the foreground the electric motor, with the interrupters, will be found, as well as incandescent lamps serving as resistances. The instrument placed behind is a new type of revolution indicator, which need not be described here. The experiments are now carried out in the following manner:

To begin with, the engine is turned until the H.P. piston is at its highest point, and then the relative positions are accurately determined, for both platinum points, with regard to the zero position of the shaft, in which the latter is free from strain.

It is of importance to fix this zero line with particular care. In the beginning some difficulty was experienced on account of the uncertainty as to the friction of the tunnel bearings, as well as in the stern tube, but these were overcome by marking the position of the platinum points twice, viz: after turning the engine by means of the ordinary gear ahead and astern, respectively, when the true zero position, without any sensible error, may be taken half way between these marks. In order to secure accuracy, this operation is repeated several times.

This being completed the real twisting experiment is carried out when the engines have run steadily for some minutes at the speed to be considered. Then the interrupting motor is made to run at the proper revolutions with reference to the speed of

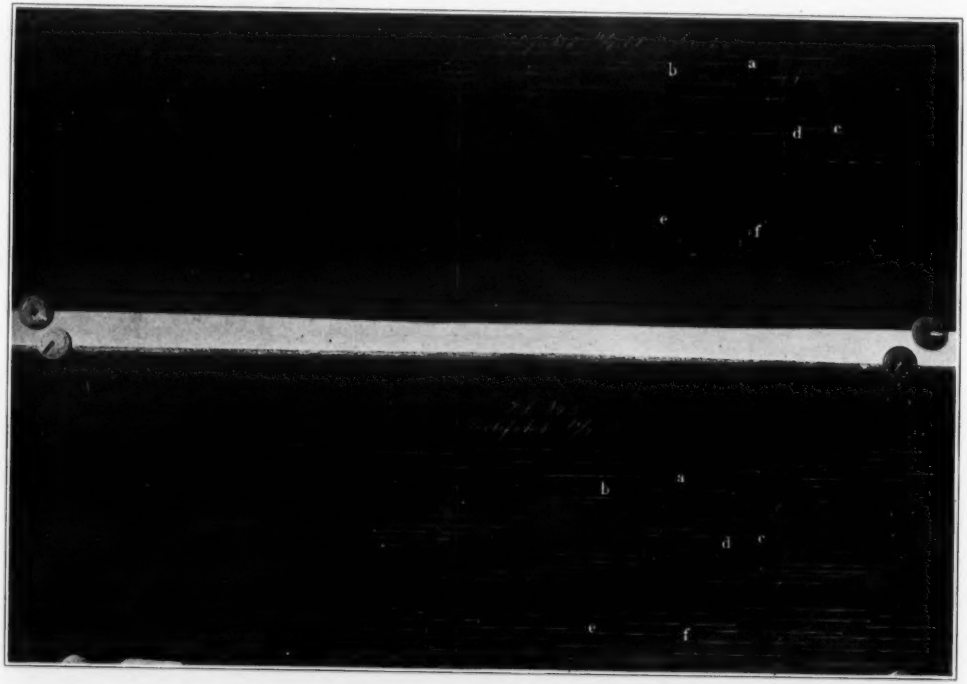


FIG. 2.—SECTION OF ZINC DIAGRAM TAKEN ON STEAMER "PRÄSIDENT."

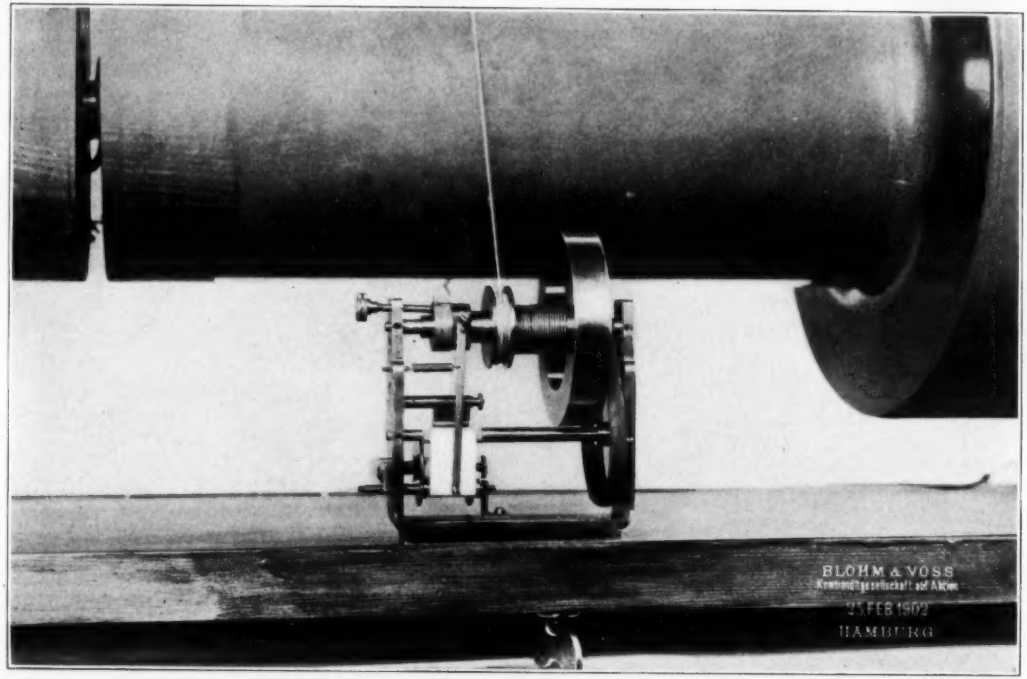


FIG. 8.—INSTRUMENT FOR REGISTERING SHAFT VIBRATIONS.

the flanges and the current in the two circuits switched on. Both the men who are in attendance at the flanges now, on a given signal, press the platinum points against the revolving zinc sheets and at the same time commence turning the screws which move the points parallel to the shaft, continuing until, another signal being given, both lift the platinum points off the flanges.

The points have then traced spiral curves on the zinc, the interruption of the current, however, make them appear more or less like dot-and-dash lines.

Fig. 2 shows a photograph of part of the zinc diagram taken on the single-screw steamer *Präsident*. These comprise three separate series of experiments, which are denoted by I, II, III. At first sight it appears difficult to distinguish the corresponding rows of marks, *i. e.*, find out which marks belong to the same revolution of the shaft, because the platinum points have not been pressed down exactly at the same instant.

On careful examination of the relative displacement of the marks in the various rows, however, one is soon able to recognize a regular reappearance of a system by which means it is easy to trace the corresponding points. In Fig. 2 the fore ends of corresponding marks are denoted by identical letters. The ticked lines, or rather their fore ends,* now furnish all the necessary information. In the first instance they enable the construction of the curve of velocity of both measuring flanges, this being due to the fact that the distances between the fore ends of two consecutive marks represent equal intervals of time, because the interruption motor is running at constant speed. The curves of velocity are then plotted, taking equal intervals of time as abscissae and the distances between consecutive fore ends of the marks as ordinates.

In order to simplify matters, we refer all velocities to the crank radius, and hence only have to apply a constant factor to the above ordinates in order to get the velocity curve desired. This factor is easily calculated from the revolutions of the engine and the average ordinate of the curve, etc.

The curves got from the two flanges may be drawn to the

*The interruption ends of the marks are not so useful, as the lines are more or less blurred by the sparks which necessarily form here.

FIG. 3.—INSTRUMENT FOR REGISTERING SHAFT VIBRATIONS.

same basis, care being taken to adjust the abscissae of time so that they correspond exactly.

Fig. 3 represents such curves for a case which will be described more completely later on, *a* belongs to the forward flange, *b* to the after one. The curves *c* and *d* are derived from *a* and *b*, and give the variations of speed in the middle planes of engine and propeller respectively. In order to get *c* and *d* one must transform the shafting, which in reality is made up of several pieces of varying diameter, into an imaginary shaft of constant diameter throughout, but having the same resultant elasticity.

The formula for this transformation is easily proved and takes the general shape

$$\frac{L_0}{l_0} = \left(\frac{D_0}{d_0}\right)^4 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where L_0 denotes the length and D_0 the diameter of the piece of shafting to be transformed and l_0 and d_0 the corresponding values for the equivalent imaginary piece, whose diameter may conveniently be taken equal to the diameter of the intermediate shafting.

Fig. 4 shows graphically how in the case of the S. S. *Besoeki* the total length of transformed shafting is composed of parts derived from the various portions of the real shafting calculated by means of (1).

In this way new distances are found between the middle planes of engine and propeller, and between the diagram flanges; these distances are denoted by L_1, L_2, L_3 (see Fig. 4).

It is easily understood how the turning speeds at a point of the shafting may be found, as soon as the speeds at any two planes are known. As a matter of fact, the relative twist between any two cross sections must be directly proportional to the distance between them, and this relation also holds good for the relative speeds. In our case we know the turning speeds in the planes II and III by direct measurement, and want the ones belonging to I and IV. Taking into account what has been said above, the following equations for the velocities at the time: t,

$$\frac{v_c - v_b}{v_a - v_b} = \frac{L_1 + L_2}{L_2} \text{ and } \frac{v_a - v_d}{v_a - v_b} = \frac{L_2 + L_3}{L_2}$$

from which v_c and v_d are easily calculated.

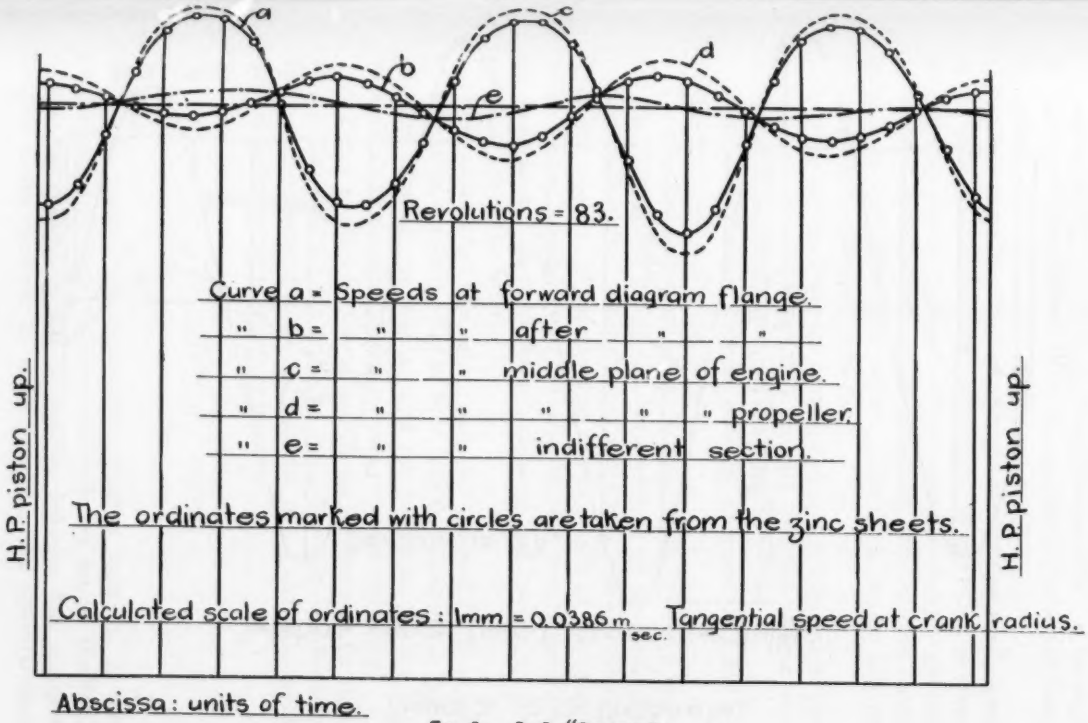

a
b
c
d
e
Revolutions = 83.
Curve a = Speeds at forward diagram flange.
" b = " " after " "
" c = " " middle plane of engine.
" d = " " " " " propeller.
" e = " " indifferent section.
H.P. piston up.
H.P. piston up.
The ordinates marked with circles are taken from the zinc sheets.
Calculated scale of ordinates: 1mm = 0.0386 m/sec. Tangential speed at crank radius.
Abscissa: units of time.

FIG. 3.—S. S. "BESOEKI."

Three cranks at 120 degrees. Degree of fluctuation: Forward, $a = 49.1$ per cent.; aft, $d = 18.9$ per cent.
Speed curves found experimentally.

Figure 5. S.S. "Besoeki."

Twisting curve, found experimentally.

Looking at Fig. 3 we find one more speed curve *e*. It belongs to that cross section which shows the smallest variations of turning speed.

As soon as we have to deal with greater twisting oscillations of the shaft, such as, for instance, in Fig. 3, we find that this cross section very closely coincides with the common center of gravity of moving parts of engine and propeller, their masses being reduced to the crank-circle radius. This cross section will be denoted the "indifferent" section.

As seen in Fig. 3, all the curves, *a*, *b*, *c*, *d*, *e*, intersect in the same points, in accordance with the fact that the various sections at that instant all have the same velocity.

From the zinc-sheet diagram we may, moreover, find the instantaneous twist of the shaft, thus:

The zinc sheets are placed next to one another in such a manner that the marks giving the zero position of the shaft and highest point of H.P. piston correspond exactly with one another. Then the relative displacement of the fore ends of the marks which belong together gives the instantaneous twist of the shafting between the diagram flanges, measured, of course, on the outer surface of the latter.

These amounts of twist may, just like the speed curves, be plotted to an abscissae scale of time, and then furnish an exact diagram showing the variations of the twist and thereby the changes which the transmitted turning moment undergoes.

In Fig. 5 is shown a curve derived in this manner for S. S. *Besoeki*, denoted by *f*, the ordinates being drawn to double scale. The twisting moment which corresponds to a given amount of twist is given by the well-known formula:

$$M_d = \frac{s\, I_p\, G}{\frac{D}{2} L_2}$$

where M_d denotes the transmitted turning moment, I_p the polar moment of inertia of the cross section of tunnel shafting, L_2 the transformed length of shafting between the diagram flanges, D the diameter of these flanges, s the instantaneous

amount of twist measured on the flanges, and G the modulus of elasticity for shear of the shaft.

In the following calculation it is preferable instead of the turning moment to introduce the turning force referred to the crank radius.

This is expressed by

$$P = \frac{M_d}{R} = \frac{s\, I_p\, G}{R \times \frac{D}{2} \times L_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where R denotes the crank radius.

The instantaneous turning force is then proportional to the corresponding amount of twist s, hence it follows that the curve which represents the amounts of twist gives the magnitude of the turning forces by proper modification of the scale. The mean ordinate of the twist curve hence also gives the mean turning force*, by means of which the mean energy transmitted to the propeller may be found by the expression

$$A = P_m \frac{n \times 2R\pi}{60 \times 75}$$

where A denotes the number of horsepower absorbed, P_m the average turning force, and n the corresponding number of revolutions per minute.

In order to calculate the transmitted forces accurately by means of the measured amounts of twist one must know the modulus of elasticity for shearing of the shafting.

As no suitable data were available from the technical literature, Messrs. Blohm & Voss determined not to start on possibly erroneous assumptions but had the modulus found by special experiment.

For this purpose three experimental shafts of 2,500 millimeters length by 60 millimeters diameter were ordered in the spring of

* The average turning force, found in this manner, is, theoretically speaking, not quite correct, as the turning-force curve really ought to have been set off to a scale of distance traveled through by the force, and not to a scale of time. Repeated comparisons of results show that in this case the mean ordinate of the curve is not affected hereby.

1900, from each of the following firms: Friedr. Krupp, Essen; Bochumer Verein, Bochum; Gewerkschaft Witkowitz, Witkowitz in Mähren, stipulating that they were to be made from the same material and treated in the same way as marine shafting proper.

These experimental shafts were sent to the Mechanisch-Technische Versuchsanstalt at Charlottenburg, and subjected to exhaustive torsion tests.

The results of these careful tests show that the modulus of the material experimented upon (Siemens-Martin steel of 40 to 47-kilograms breaking strength per sq. mm. and over 20 per cent. elongation) varies by remarkably small amounts, and very nearly agrees with the average value, 828,000 kilograms per square centimeter.

This figure was then made use of to determine the effective power transmitted, and thus the ratio which it bore to the indicated horsepower—*i. e.*, the mechanical efficiency of those engines—could be found.

As far as I know, the so-called brake horsepower of engines developing several thousands horsepower has never been measured accurately before this. The method which, practically speaking, makes use of the shafting as a torsional spring can, of course, only be applied to marine engines having these long shafts, or to installations with long-shaft transmissions.

The efficiency in the cases examined varied between 92 and 88 per cent.* Lower values, down to 82 per cent., were only found in special cases, and particularly at the critical revolutions to be considered later. I estimate the accuracy which may be attained in these experiments at .5 to 1.0 per cent. This also is about the degree of accuracy which one may, at most, expect when calculating the I.H.P. from indicator cards.

Turning now to the experiments themselves, I may state that the chief object aimed at was the study of possibly-appearing synchronous vibrations. By ordinary means it is impossible to notice their existence. They may take place during the normal running of the machinery, and consist of harmonical to-and-fro

* Later on an efficiency of 93.5 per cent. has been found for an engine of 4,500 H.P.

vibrations of the engine and propeller masses, causing more or less violent twisting actions in both directions in the shafting.

This torsion, which is only caused by the vibrations, starts from a zero position, which is determined by the average amount of twist, corresponding to the mean turning moment transmitted.

The resulting twist is, then, the sum of these actions, and sometimes greater, sometimes smaller, than the twist due to the average turning moment.

The conditions which govern the existence of the synchronous vibrations are satisfied when the period of the variations of the crank effort curve equals or approaches the natural period of vibration of the shaft with its terminal masses attached.

This latter period is approximately given by

$$n_e = \frac{30}{\pi R}\sqrt{\frac{G I_p (m_1 + m_2)}{L m_1 m_2}} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where n_e is the number of vibrations per minute; m_1 and m_2 the masses of engine and propeller respectively, referred to the crank radius, and L the total length of shafting (transformed). The remaining letters have the same meaning as before.

The period of variation of the crank effort depends upon the revolutions of the engine, the number of variations per minute being respectively one, two, three, four, etc., times the number of turns.

When, in this case, the expression "variations" is used, it is to be understood that this implies all the harmonical curves into which any crank effort diagram, however complicated, may be resolved by means of Fourier's theorem.

This expresses that any periodical function $T = f(\varphi)$ can be split up thus

$$T = H_0 + H_1 \cos(\varphi + \varphi_1) + H_2 \cos(2\varphi + \varphi_2) + H_3 \cos(3\varphi + \varphi_3) + \quad . \quad . \quad . \quad (4)$$

where H_0, H_1, etc., denote coefficient and φ_1, φ_2, etc., the angular phases. In order to simplify the finding of these values, it is convenient to write (4) thus:

$$T = H_0 + A_1 \cos\varphi + A_2 \cos 2\varphi + A_3 \cos 3\varphi + \quad . \quad . \quad . \\ + B_1 \sin\varphi + B_2 \sin 2\varphi + B_3 \sin 3\varphi + \quad . \quad . \quad . \quad .$$

when no angular phases appear, but only two series of coefficients, which may be found from the integrals:

$$A_i = \frac{1}{\pi}\int_0^{2\pi} T\cos i\varphi\, d\varphi$$

$$B_i = \frac{1}{\pi}\int_0^{2\pi} T\sin i\varphi\, d\varphi.$$

The integrations necessary can only be carried out graphically by first plotting the values $T\cos i\varphi$ and $T\sin i\varphi$ to scale, and then integrating by planimeter.

When A_i and B_i have been found in this manner, the unknown quantities in (4) may be found by means of the relations

$$H_i = \sqrt{A_i^2 + B_i^2}$$

and

$$\tan \varphi_i = \frac{A_i}{B_i}$$

H_0 is found by $H_0 = \frac{1}{2\pi}\int_0^{2\pi} T\, d\varphi$, which expresses that H_0 is equal to the mean ordinate of the curve of T.

This constitutes the so-called harmonical analysis of the crank effort diagram, where the amplitudes are H_1, H_2, etc., and the phases φ_1 and φ_2, etc., belonging to the elementary curves wanted.

As illustration, Fig. 6–A, B, C, D, shows the analysis for the S. S. *Besoeki*, the revolutions being 83 per minute. Only the three first elementary curves are found, as in this case the higher orders do not play any part.

The full-drawn line *g*, Fig. 6–A, shows the resultant of the three harmonical curves. As this differs only very little from the real crank-effort curve, it seems safe to assume that the harmonical curves of higher order are but of small importance.

In order to maintain a uniform notation, we shall consider the fundamental curves as being of the I, II, III order, respectively, when they have their number of periods per minute in proportion, as 1, 2, 3, etc., to the corresponding number of revolutions of the shaft.

FIGS. 6—A, B, C, D.

Harmonical analysis of the diagram of crank effort at 83 revolutions.

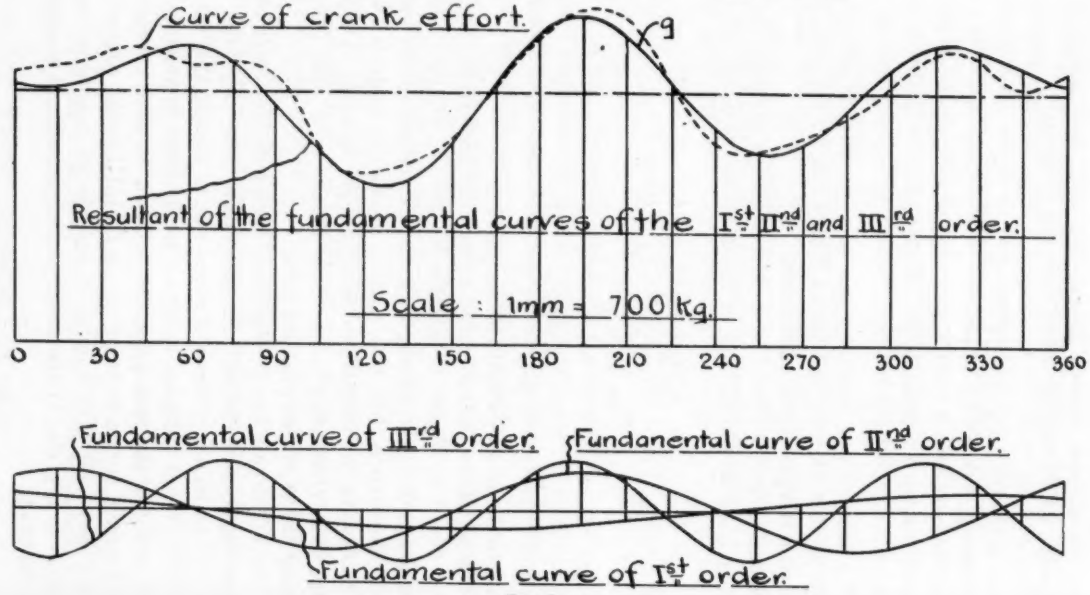

Curve of crank effort.
g
Resultant of the fundamental curves of the I^st II^nd and III^rd order.
Scale : 1mm = 700 kg.
0 30 60 90 120 150 180 210 240 270 300 330 360
Fundamental curve of III^rd order.
Fundanental curve of II^nd order.
Fundamental curve of I^st order.

FIG. 6—A.

Fundamental curve of 1st order.

FIG. 6—A.

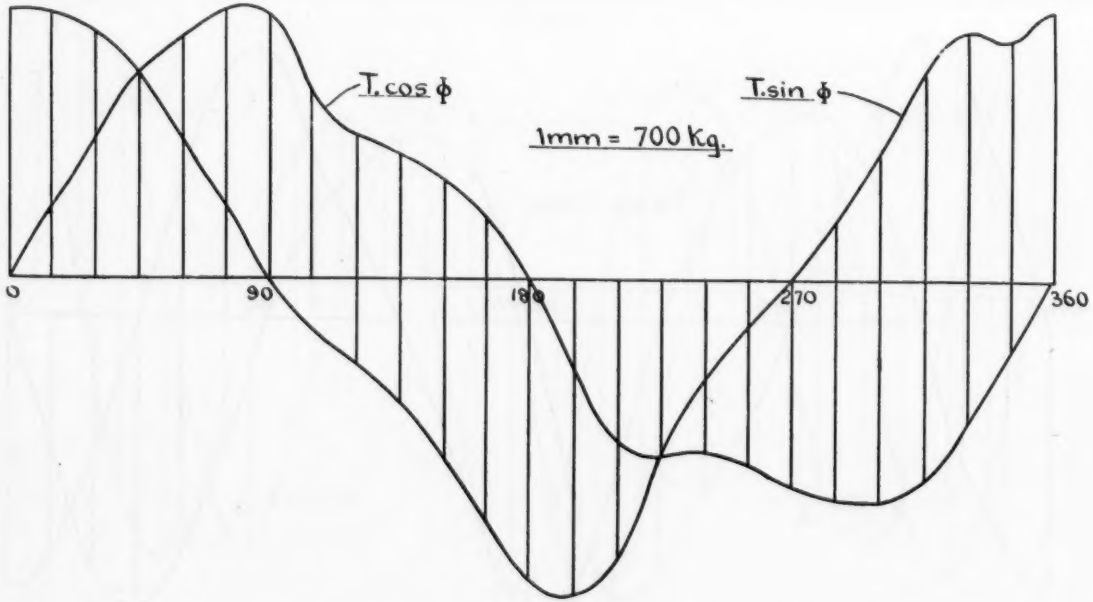


FIG. 6—B.

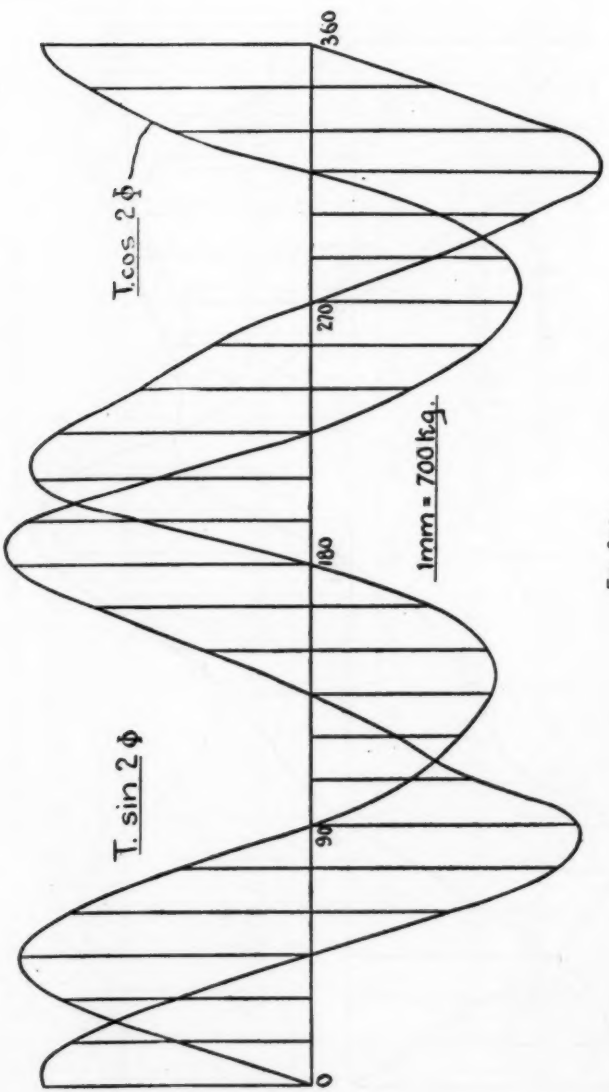


Fig. 6—c.

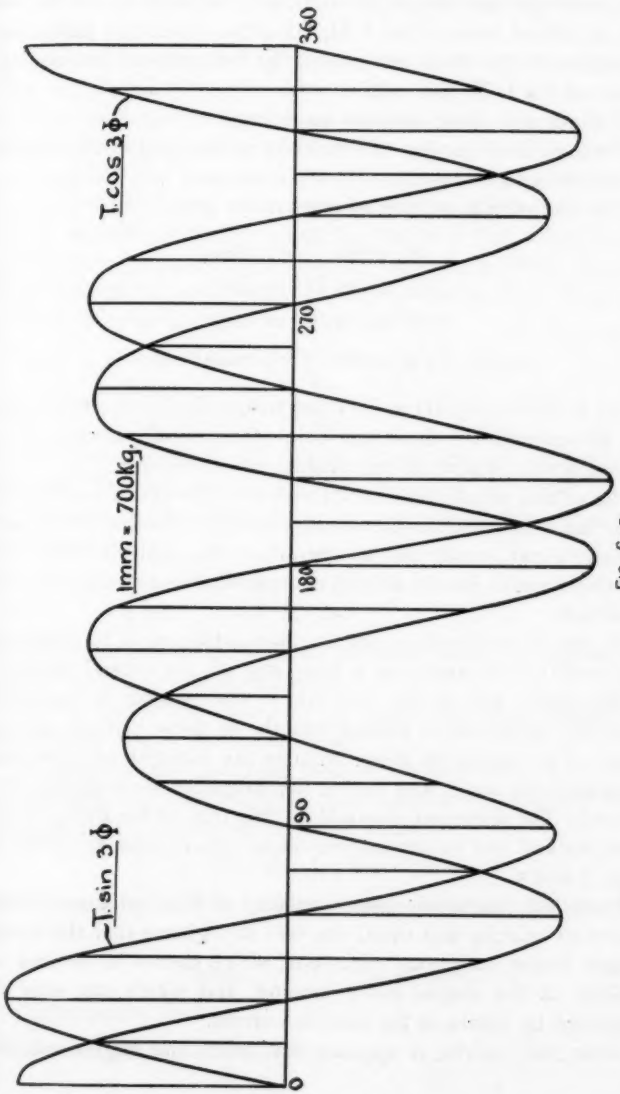


FIG. 6—D.

Accordingly we denote the number of revolutions of the engine as critical ones of the I, II, III order, when the individual vibrations of the shaft are caused by fundamental harmonical curves of the I, II, III order.

To make this clear, consider an example:

The individual number of vibrations of the shaft of the *Besoeki* is, according to calculation, 257.4 per minute.

Then the critical number of revolutions are

$$\text{Ist order } \frac{257.4}{1} = 257.4.$$
$$\text{IId order } \frac{257.4}{2} = 128.7.$$
$$\text{IIId order } \frac{257.4}{3} = 85.8.$$
$$\text{IVth order } \frac{257.7}{4} = 64.4.$$

Out of these only III and IV are within the limits of the case, and fall respectively above and below the normal running of the engine, which is at 70 to 72 revolutions per minute.

The critical revolutions of III order in this case are of special importance, because the harmonical curve of III order shows particularly great amplitudes, as seen from the analysis (Fig. 6-D) and therefore, as will be shown, causes vibrations of considerable amplitude.

On the *Besoeki* and on another later steamer, S. S. *Radames*, the normal revolutions are a long way off the critical numbers of III order; yet on the trial trip it was possible to make the described experiments almost exactly at these critical revolutions. This could be done, because the draught of water was comparatively small, and hence the propeller incompletely immersed. The diagrams obtained on this trial of the *Besoeki* have been worked out in the manner shown above, and are given in Figs. 3 and 5.

From the magnitude and regularity of the variations in the curves of velocity and twist, one sees at a glance that the whole system makes enormous vibrations, which cannot be noticed by looking at the engine while running, and which can only be measured by means of the electric current.

From the curves, it appears that when the engine vibrates

ahead the propeller always vibrates in the opposite sense, and *vice versa*.

The magnitude of the vibrations is most clearly seen from the diagram of twist (Fig. 5). This shows that during one revolution the shaft gets strained by a moment equal almost to three times the transmitted average turning moment, and, in between, springs back past the neutral zero line a long way into the negative region of strain. At some points, then, the kinetic energy of the propeller actually draws the engine along. The shaft, of course, gets strained intermittently to an extent which considerably exceeds the safe limit. When calculating from these data we find the pure torsional stresses τ to be

τ mean = 218.4 kilo. per sq. cm.
τ max. = 600 " " "
τ minim. = —166 " " "

In the propeller shaft still higher values appear. Taking into account the bending caused by the weight of propeller, as well as the oblique application of the thrust,* we find the combined bending stresses:

k mean = 505 kilo. per sq. cm.
k max. = 851 " " "

and these values are still further increased when the engine runs exactly at the critical revolutions 85.8.

On the trial of the *Besoeki* it was unfortunately not possible to experiment at this particular speed.

Theoretical considerations, to be given later on, as well as the results from the *Radames*, also to be considered presently, show that certainly a maximum torsional stress of

τ max., 810 kg. per sq. cm.,

would occur in the intermediate shafting, together with an equivalent, combined stress

k max., 1030 kg. per sq. cm.,

in the propeller shaft.

* Due to incomplete immersion in this case.

Considering that these great stresses occur three times during one revolution, and in between even become negative, it is not to be wondered at that sooner or later the shafting breaks down with engines where the normal revolutions accidentally coincide with the critical ones. In such cases also, according to the above figures, it is the propeller shaft which is liable to go first, in spite of it being heavier than the intermediate shafting.

It is only possible to insure the necessary superiority of strength of the propeller shaft over the intermediate shafting by a further increase of the dimensions of the former, such as is now contemplated or decided upon by the register societies, due to pressure of circumstances.

The roots of the propeller blades undergo alternating strains in a similar way. In the *Besoeki* the calculated tension of the cast-iron blades varied between +480 kilograms per square centimeter to —50 kilograms per square centimeter.

The main point which arises from the above experiments is that in the future the critical revolutions must be taken into account when designing the engines, and one must arrange these revolutions so that they are as far away from the normal ones as possible.

To obtain this, use the equation (3) giving the individual numbers of vibrations of the shaft. The masses of the engines and propellers and the length and diameter of the shafting enter as variable quantities.

Of this, the two first-mentioned ones are fixed beforehand by the design, while the transformed length of shafting, which is important as regards the vibrations, is determined by the position of the engine in the ship and thus settled by considerations regarding the hull.

Hence only the diameter of the shafting can be changed. This, however, proves most effective for the purpose of altering the natural period of the shafting and thereby the critical revolutions.

We now proceed thus:

First the shaft is selected according to the rules of the register. Then the natural period of it is calculated and the critical number of revolutions derived. If, now, one of these fall near the

normal revolutions of the engine, or coincides with them, the diameter will have to be altered. At the present time this means an increase of the diameter.

Only when the register societies have made themselves familiar with these so far unknown dynamical actions in the shafts it may be hoped that in some cases a reduction from the rules for the diameter will be allowed, whereby one of the critical number of revolutions may be lowered away from the normal revolutions. The average strain in the shafting would hereby be increased. The dangerous dynamical actions would, however, be eliminated.

So far we have only spoken in general terms about the critical revolutions, without specially considering their order.

The latter point is of importance, as sometimes one has to particularly avoid those of the IId, sometimes those of the IIId, order. The extent to which the individual orders are dangerous is seen by the amplitude of the corresponding fundamental harmonical curve of turning force, which will be shown later. As far as my experience goes, fixed rules cannot yet be framed, and every designer must, in this respect, investigate the case for himself. Only this much may be pointed out, that when dealing with engines having three cranks at 120 degrees, the IIId order, sometimes also the IId order, become particularly dangerous. In the case of 4-crank engines, there appears to be still less regularity of the rule. Sometimes the IIId, sometimes also the IId order or the IVth give the greatest amplitudes. This uncertainty is partly due to changes in distribution of the steam energy when varying the cut off in the individual cylinders, partly to the varying sequence of the cranks, and particularly to variations of their angular intervals.

So far the experiments seem to indicate that the Vth and higher orders are of practically no importance, the corresponding harmonical curves showing very small amplitudes, and consequently they will only be able to generate feeble and harmless vibrations.

Still such vibrations exist, as is proved by the diagram from S. S. *No. 145*, Plate I–E, where the curve denoted *h*, which represents the turning force, shows five marked elevations. This diagram was taken with the ship in moorings. The revolutions

were 59, *i. e.*, about one-fifth of the natural number of vibrations of the shaft, which was calculated at 284.3 per minute.

Another important question also to be solved, was whether and to what extent the appearance of these vibrations depends on some definite number of revolutions. This also has been settled by the experiments and by theoretical calculations, which will be explained presently. Fig. 7 shows graphically the character of the transmitted turning forces at various revolutions, viz: from 77 upwards past the dangerous critical number of IIId order at 83, and on to 89.

The curves, drawn in full, were determined directly by experiment, the dotted ones were completed by estimating or calculating them. From this may be seen that no sharply defined critical speed exists; already at a few revolutions above and at a few below the vibrations show a dangerous character. Consequently one must select such diameters for the shafts as will insure a difference of some 8 to 10 revolutions from the normal ones.

After having thus demonstrated two striking cases, as I hope, in a plausible manner, I will now proceed to show that the coincidence of normal and critical revolutions is a quite possible one for a good many actual engines.

For this purpose I have had the annexed Table I, page 756, compiled, which gives the calculated individual vibrations, as well as the critical revolutions deduced therefrom. The engines were selected at random from a lot of data of machinery at my disposal. It appears in a striking manner from this table, how far one has hitherto gone wrong in neglecting the synchronous vibrations. In almost all the cases considered either IIId or IVth order of critical revolutions are more or less in vicinity of the normal revolutions.

For this reason one may assume that many marine engines have been running nearly at the critical speed for years, and it is not at all to be wondered at when at last a fracture occurs.

It is not my intention to frighten the parties concerned, but still I recommend owners and shipping companies to have their engines examined as regards these vibrations, in order to alter the individual period of vibration of the shafting if necessary.

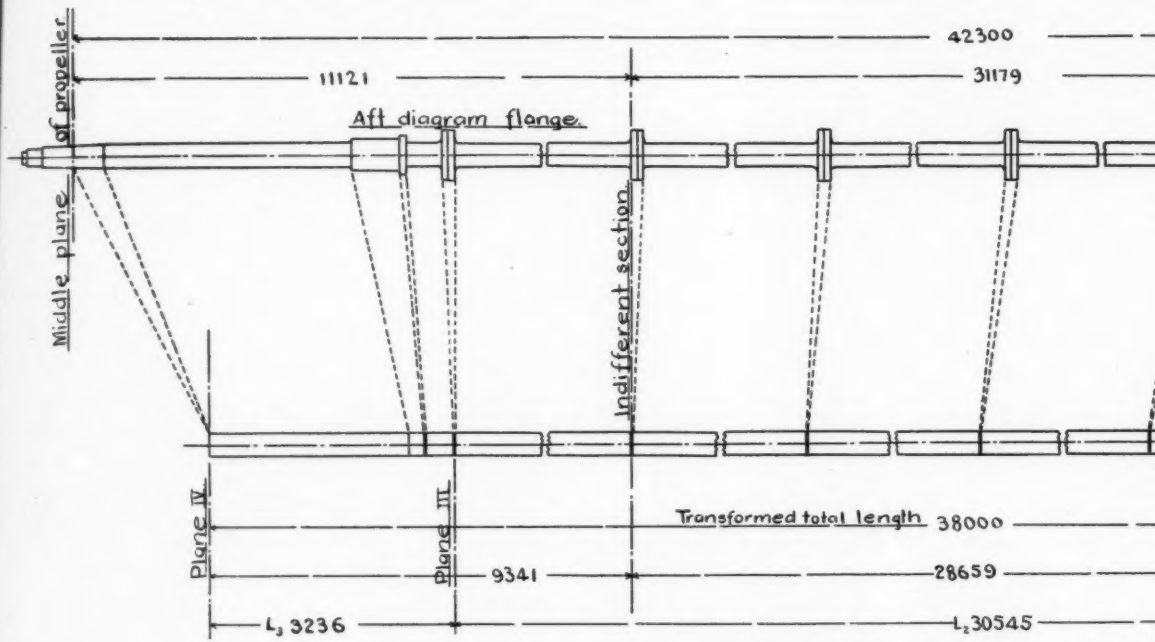


FIG. 4.—REAL AND TRANSFORMED SHAFTING

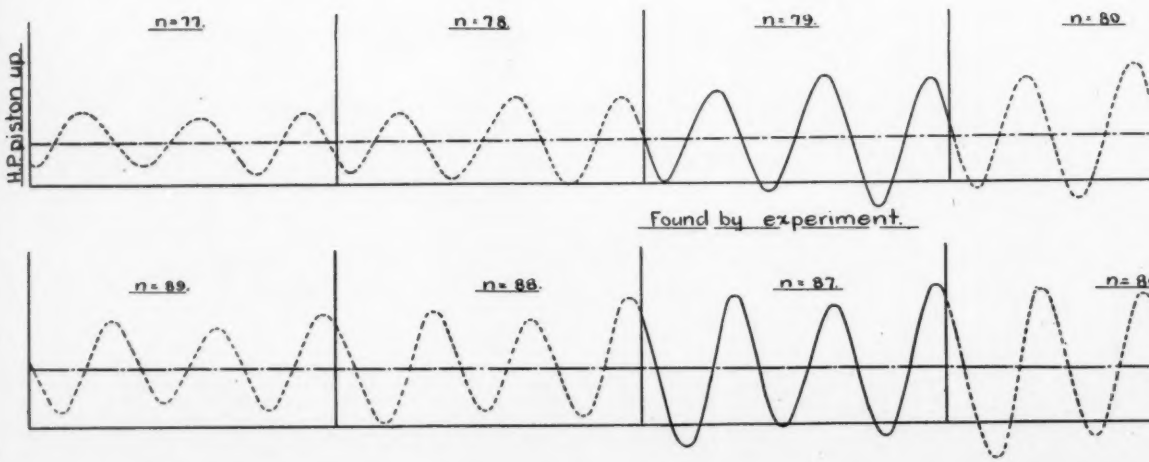
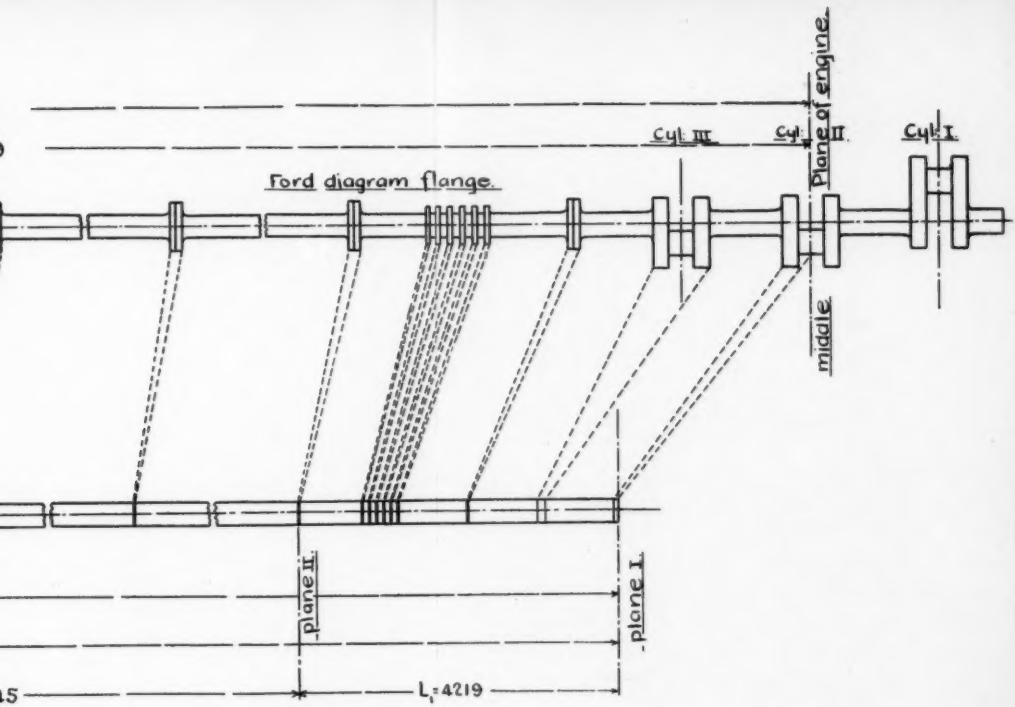
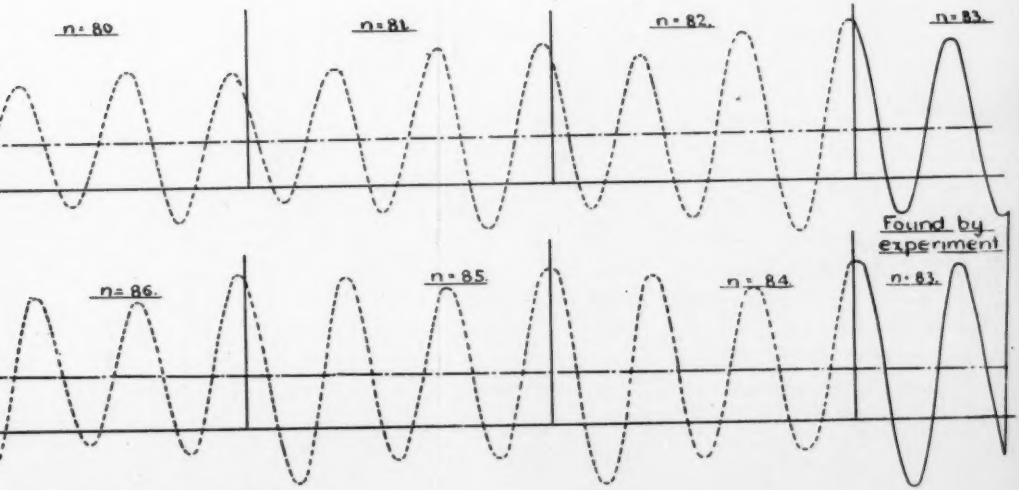


FIG. 7.—CURVES OF SHAFT TWISTING, S



SHAFTING OF S. S. "BESOEKI."



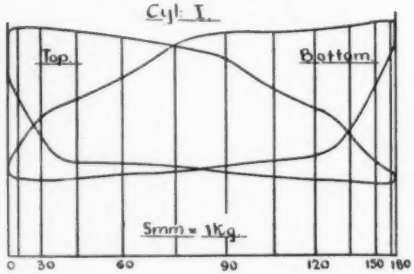
TWISTING, S. S. "RADAMES."

Figure 10. S.S. "Besoeki."

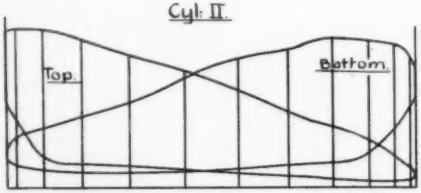
Revolutions = 83.

Indicator cards.

Cyl: I.

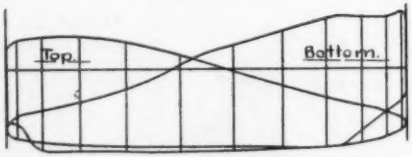


Cyl: II.



10mm = 1Kg.

Cyl: III.

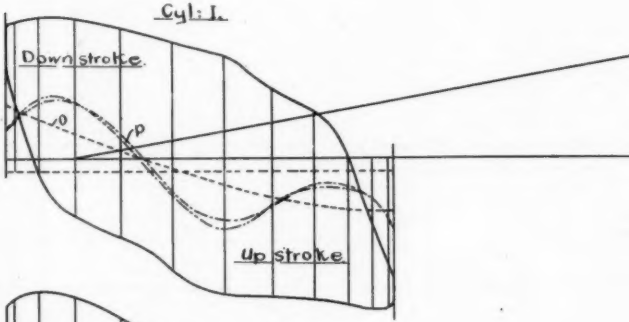


30mm = 1Kg.

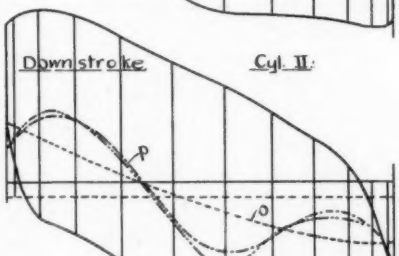
Piston force diagrams.

Scale of force = 1mm = 980kg.

Cyl: I.



Cyl. II.

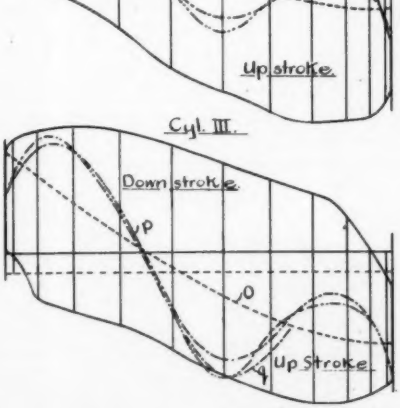


O ------- Curve of

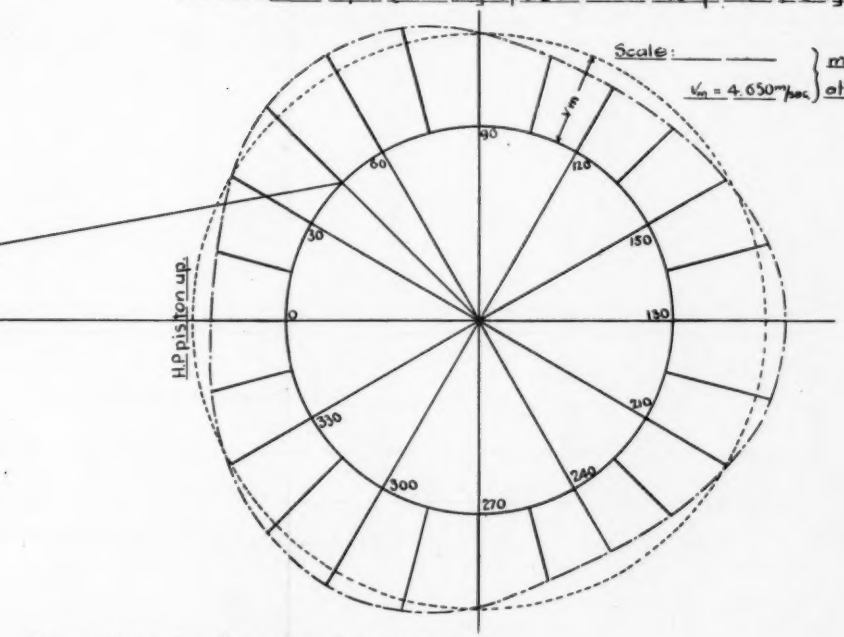
P { ---- Upstroke
---- Down stroke.

Curve of

Cyl. III.



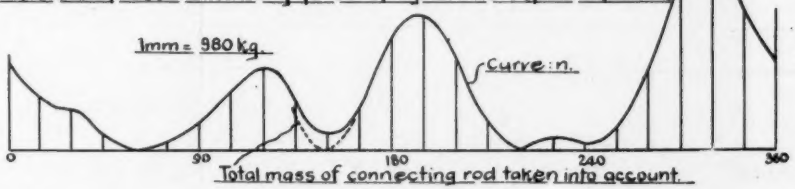
——·——·—— Curve of real turning speed in middle plane of engine.



– – Curve of acceleration at constant speed.

—— Upstroke
—— Down stroke } Curve of acceleration due to real speed of turning (by experiment).

Curve of steam pressure turning force of Cyl III. at real speed of crank.



Total mass of connecting rod taken into account.

Another important side of this question lies in the fact that not only the efficiency of the engine is reduced by the vibrations which I have found on the *Besoeki*, but also the propeller efficiency suffers considerably by the great variation of speed, a result which is obtained by several observations and investigations, too lengthy to be considered here.

In order to determine the critical number of revolutions of a completed marine engine one may resort to calculations or to experiments. The former method may only be used when complete data of the engine are available.

This is only rarely the case, particularly with engines built abroad, and hence the other method must be resorted to. It is carried out by starting the engine at low speed and increasing the revolutions gradually, noting the speed when the vibrations appear.

For this purpose an instrument is needed which makes the vibrations visible to the eye. Fig. 8 is a photo of my design for it. It is based on the relative movement of a small, light pulley driven by the shaft, and a flywheel spinning at the same average speed. These relative movements are made to trace a curve on a sheet of paper by means of a suitable mechanism.

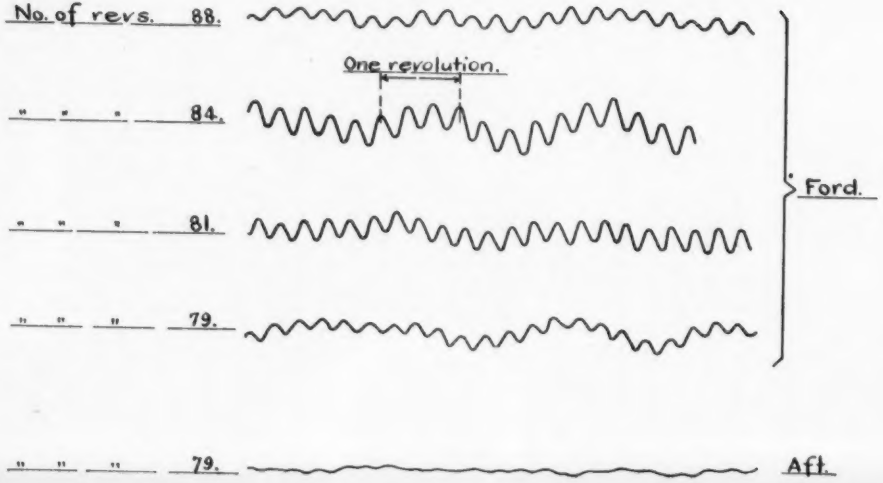
This instrument does the same work, as regards the invisible vibrations of shafts, as Schlick's pallograph with regard to the visible vibrations of ships. I have often used the instrument to check the calculated critical speeds, and have always found good coincidence.

Fig. 9 shows the diagrams of the *Besoeki* combined, where the revolutions 85 show the greatest amplitude, and thus marks the critical speed. As three vibrations occur for one turn, the order must be the 3d.

Returning now to our original experiments, I beg to refer to Plate I–A, B, C, D, E, F, G, where a short extract is shown, compiled from the extensive results of the last year. This is of interest, as it shows that for all sorts of engines, even when running at speeds far from the critical ones, the turning forces, as transmitted, do not in the least coincide with the forces as calculated from the indicator cards. In most cases they are directly

Figure 9. S.S. "Besoeki"

Diagrams for determining the critical number of revolutions taken by instruments.



opposed to these latter ones, and always so when the revolutions of the engine in question are above the corresponding critical ones (Diagr. 139, 142, 144). If the revolutions fall below the critical ones, then the general run of the curves agrees (Diagr. 140, 145), yet the amplitude assumes quite different values.

The most uniform run of all is found in No. 144, which is taken from an engine balanced on Schlick's principle. This fine result is partly due to the uniformity of the turning force, but chiefly to the fact that the engine runs at revolutions far above the critical speed of IIId order. In accordance with this, the engine works particularly smoothly and quite free from shaking.

Having so far considered the influence of the vibrations on the shafting, we shall proceed to investigate what takes place in the engine itself at the same time.

For this purpose Fig. 10 shows the effective piston forces for the *Besoeki* at 83 revolutions, which is approximately the critical speed. The forces are drawn in the usual manner, and in one case those due to inertia are drawn for constant speed (curves o), in the other case taking into account the turning speed experimentally found (curves p).

Especially at the L.P. cylinder one notices the enormous effect of the degree of variation of speed (0.49). About the middle of the stroke this causes such an increase of inertia force that during the down stroke the resulting driving force delivered by the piston rod amounts to 1.66 times the normal force, whilst during the up stroke the force becomes almost zero. Drawing these curves, only the directly reciprocating masses have been considered, whilst at half stroke the whole of the connecting rod ought to be reckoned as well; hence for a short time we get a real negative force on the crank pin (see curve 9). This was corroborated by a powerful and unpleasant shock in the bearing at half stroke.

The part of the turning-force diagram which is supplied by the L.P. cylinder is shown in the curve n, which instead of the usual two zero points now possesses three such ones, in accordance with the above-mentioned facts.

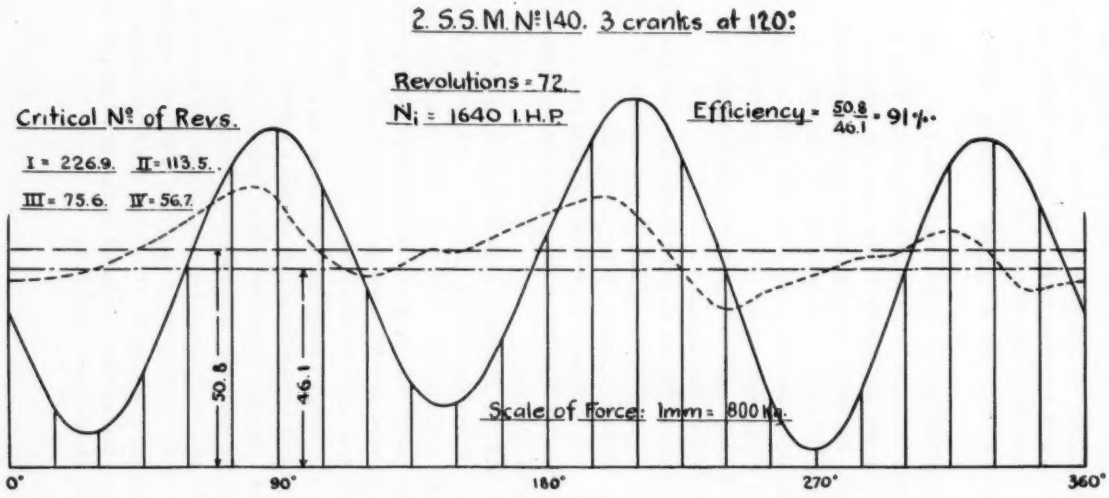


PLATE I—A.

On these plates { ——— = curves of turning force transmitted by shafting, as found by experiment.
{ ------- = curve of turning force from indicator cards.

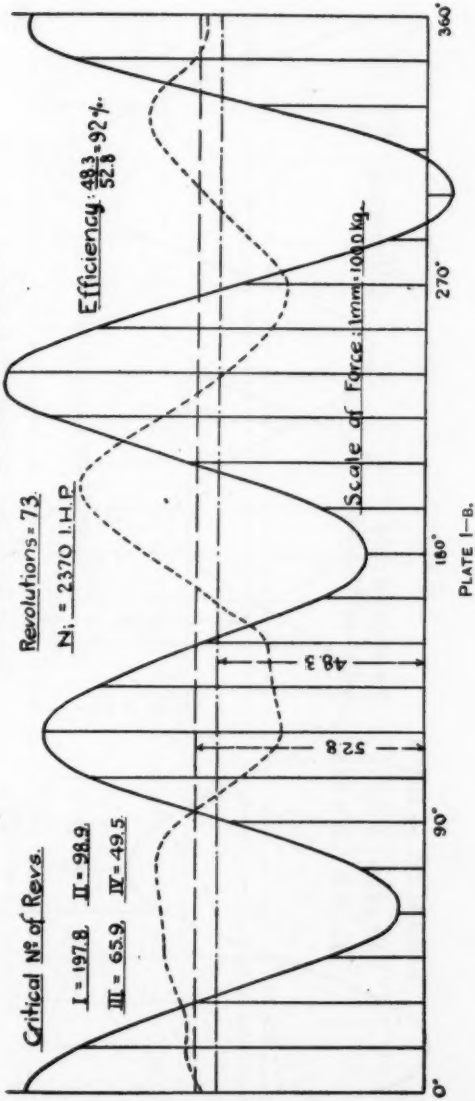
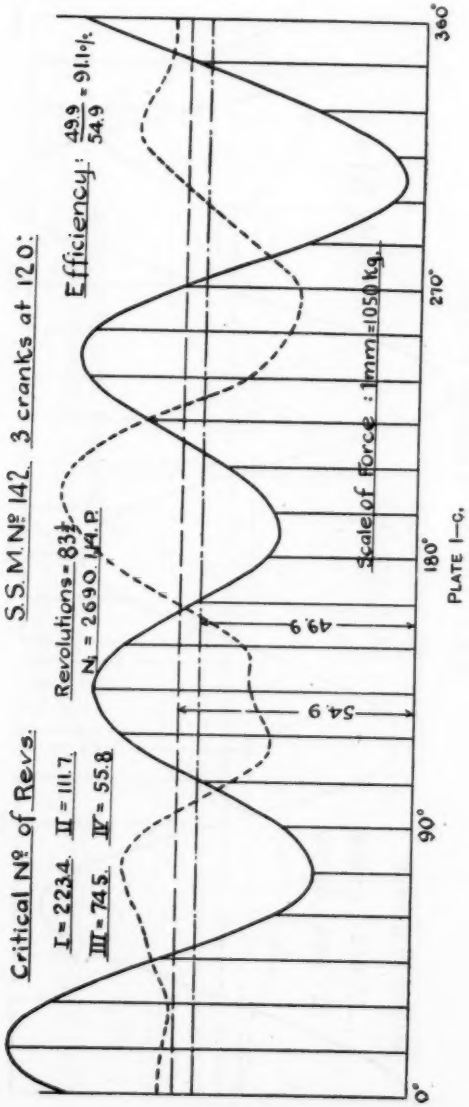

2 S.S.M. Nº 139. 3 cranks at 120°.
Revolutions = 73.
Ni = 2370 I.H.P.
Efficiency: 48.3/52.8 = 92%
Scale of Force: 1mm = 1000 kg.
Critical Nº of Revs.
I = 197.8. II = 98.9.
III = 65.9. IV = 49.5.
52.8
48.3
0°
90°
180°
270°
360°

PLATE I—B.


S.S. M. Nº 142. 3 cranks at 120°
Efficiency: 49.9/54.9 = 91.1%
Critical Nº of Revs.
I = 2234. II = 111.7.
III = 745. IV = 55.8
Revolutions = 83½
N = 2690 I.H.P.
49.9
54.9
Scale of force : 1mm = 1050 kg.
0°
90°
180°
270°
360°
PLATE I—C.

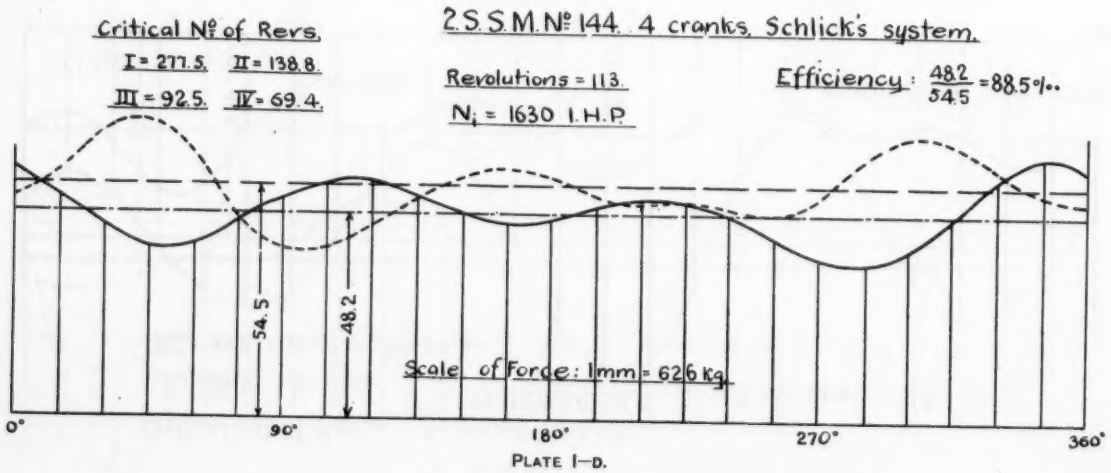

Critical Nº of Revs.
I = 277.5. II = 138.8.
III = 92.5. IV = 69.4.
2.S.S.M. Nº 144. 4 cranks, Schlick's system.
Revolutions = 113.
Ni = 1630 I.H.P.
Efficiency: 48.2/54.5 = 88.5%.
54.5
48.2
Scale of Force: 1mm = 626 kg.
0°
90°
180°
270°
360°

PLATE I—D.

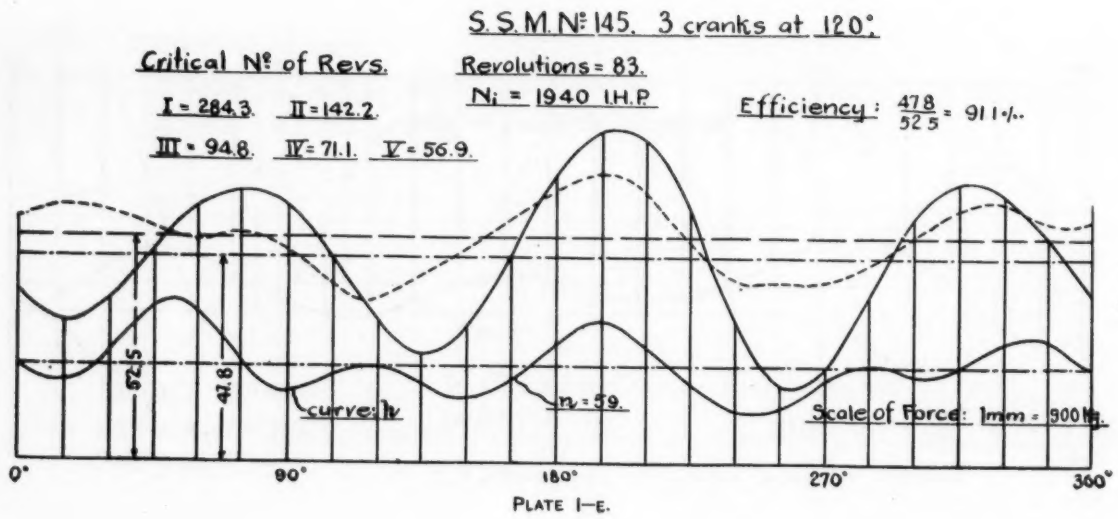

S.S.M.N° 145. 3 cranks at 120°.
Critical N° of Revs.
I = 284.3. II = 142.2.
III = 94.8. IV = 71.1. V = 56.9.
Revolutions = 83.
Ni = 1940 I.H.P
Efficiency: 478/525 = 91·1%.
52.5
41.8
curve: Iv
n = 59.
Scale of Force: 1mm = 900 lb.
0°
90°
180°
270°
360°

PLATE I—E.

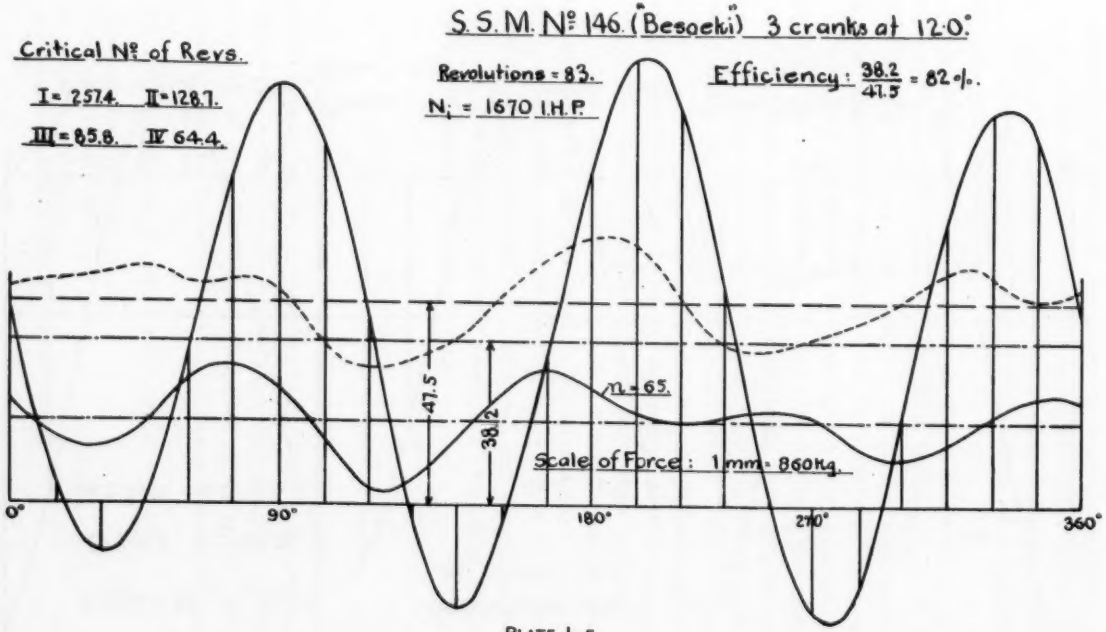

S.S.M. Nº 146. ("Besaeki") 3 cranks at 120°
Critical Nº of Revs.
I = 257.4. II = 128.7.
III = 85.8. IV 64.4.
Revolutions = 83.
N_i = 1670 I.H.P.
Efficiency : 38.2/41.5 = 82 %.
47.5
38.2
n = 65.
Scale of Force : 1 mm = 860 Kg.
0°
90°
180°
270°
360°

PLATE I—F.

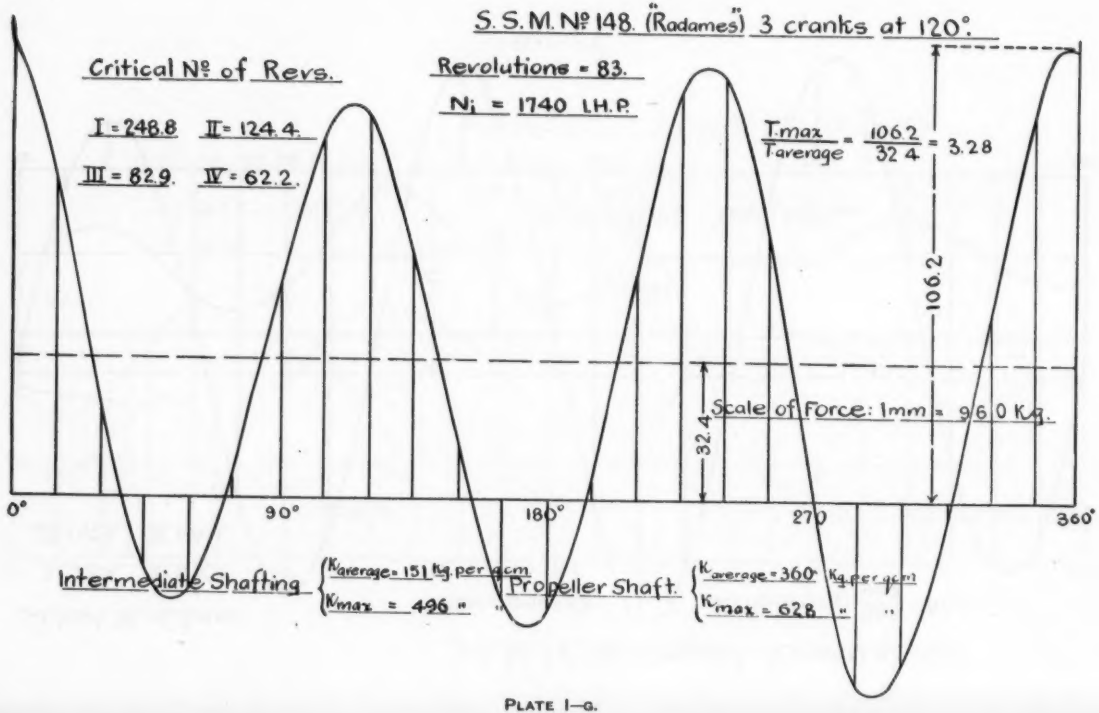

S.S.M. Nº 148. (Radames) 3 cranks at 120°.
Critical Nº of Revs.
I = 248.8 II = 124.4
III = 82.9 IV = 62.2
Revolutions = 83.
Ni = 1740 I.H.P.
Tmax / Taverage = 1062 / 324 = 3.28
106.2
32.4
Scale of Force: 1mm = 9.60 Kg.
0°
90°
180°
270°
360°
Intermediate Shafting
K average = 151 Kg. per sq.cm
K max = 496 "
Propeller Shaft.
K average = 360 Kg. per sq.cm
K max = 628 "

PLATE I—G.

Naturally the effect on the propeller is worth noticing too. It is of interest to get to know the character of the variations in the water resistance against turning, in order to find a definite law which may be used for theoretical treatment of the question presently to be investigated.

By calculation we find the mass of the propeller reduced to the crank radius, the curve *d* (Fig. 3) gives the magnitude of the speed of turning at any point, and *f* (Fig. 5) gives the corresponding turning moment transmitted from the shaft to the propeller.

By means of known laws of dynamics* it is now possible to draw the curve of resistance. This curve has been calculated, and will be found marked *i*, but does not yet represent the pure resistance due to the water, its undulations still showing a difference of phase as compared to the speed curve.

In order to eliminate this feature, one must increase the calculated mass of the propeller by an amount representing the mass of water carried along by it. The percentage necessary is about 25 per cent. This being added, the difference of phase vanishes, and thus the pure curve of resistance *k* is found, containing no forces due to acceleration of water. It is now seen to be completely synchronous with the speed, and hence admits of connecting the two by a simple relation. This may, for the velocities in question, be written thus:

$$W = Cv^r$$

where W is the resistance, C a constant, v the instantaneous speed of turning, and r the power to which v has to be elevated.

In our case r turns out to be nearly 4, which means to say that the resistances vary with the fourth power of the speed. This law differs from the law of squares, which has in some cases been

* The law in question is: $P_m - W_m = m \frac{\triangle_v}{\triangle_t}$ where

P_m = mean turning force,
W_m = mean resistance and
$\triangle_v$ = increment of speed,
m = mass of propeller, reduced to crank radius
} during time $\triangle_t$.

supposed to hold, supported, apparently, by experiments.* I therefore thought it necessary to check its correctness by further experiments.

For this purpose a number of marine engines were considered, the curves drawn as described and the corresponding indexes found. They fall between 3, 6 and 4, the mass of the water carried along by the propeller varying between 20 and 32 per cent. Further verification of these values is obtained from the data published by Mr. Froude, and from independent propeller trials which I had to carry out two and a half years ago for Messrs. Blohm & Voss at the experimental tank in Spezia belonging to the Italian government. They gave the average value of the index at $r = 3.8$ at constant speed of model (and hence varying slip).

The run of the resistance curve (k) given in Fig. 5 is of interest, as it shows no effect due to the individual propeller blades. Just because the 4-bladed propeller of the *Besoeki* was only immersed to the top of the boss, one would have expected a particularly irregular resistance on account of the changing immersion and emersion of the blades, and hence four bulges in the curve. The absence of these shows that the total resistance of all four blades can be represented as a simple function of the turning speeds, even when individual blades get subjected alternately to great alterations of load, caused by local circumstances.

This, moreover, is corroborated by the conclusions which Dr. Bauer, of Stettin, at the time drew from his experiments.

Being now acquainted with the law of resistance of the propeller we are able to analyze the dynamical actions in the shafting theoretically. Let us state the case once more. We have

*G. Bauer. "Jahrbuch der Schiffbautechn. Gesellschaft," Vol. II, 1900. The proof given for the law of squares, based on these experiments, is derived by assuming the law to hold, and then using it for building up curves, which, on comparison with the ones derived from the experiments, show a fair coincidence. In this manner one might just as well have proved any law of 1st, 3d or 4th, or even 5th, power of the speed. As a matter of fact, curves constructed according to any of these laws have been shown by experiment (and may be shown by calculation) to agree quite well, only small differences of phase occurring, whilst the amplitudes remain practically the same.

to deal with two rotating combinations of masses, the engine forming one part, the propeller the other part.

Acting in the engine, we have first of all the directly rotating masses, such as the crank shaft complete with the lower parts of the connecting rods, but also reciprocating masses, of which only a fraction, amounting on the average to *one-half*, may be reckoned as effective as regards rotation.

It is easily proved by theory that only one-half is to be reckoned. • The proof is based on the general equation for the accelerating forces due to the reciprocating masses, when referred to the crank radius. We may then imagine the various moving parts of the engine to be substituted by one single mass m_1, acting at the crank radius and in the middle plane of the engine. This will be approximately equivalent to the real engine as far as rotation goes. The mass of the propeller may similarly be substituted by a mass m_2 acting also at a radius equal to the crank, but in calculating its amount one must not forget the water carried along.

The mass of the shafting itself, which is of small importance in most cases, may, for all practical purposes be taken into account thus:

Add to the forward mass

$$0.3 m_w \frac{m_2}{m_1 + m_2}$$

and to the after mass

$$0.3 m_w \frac{m_1}{m_1 + m_2}$$

where m_w denotes the mass of the shafting transformed to the crank radius. Then we have two masses, m_1 and m_2, which are united by an elastic medium, viz: the shafting, possessing itself practically no mass; m_1 is moving almost quite freely—*i. e.*, without any dampening influence; m_2, on the contrary, is subject to such resistance.

This resistance is a function of the velocity, and may be written

$$W = Cv^r$$

TABLE I.—OF CRITICAL NUMBERS OF REVOLUTIONS.

Engine No.	System of engines and arrangement of cranks.	I.H.P.	Masses referred to crank radius in kg/cm.		Crank radius, in cm.	Shaft diameters, in cm.	Transformed length of shafting, in cm.	Normal revolutions.	Numbers of vibrations of shafting.				Engine No.
			For'd.	Aft.					Ist order.	IId order.	IIId order.	IVth order.	
1	Quadruple expansion, 4 cranks at 90°	3,500	19.88	23.35	68.6	36.8	4,980	78	232.6	116.3	77.5	56.5	1
2	(Schlick)..	2,750	18.72	30.72	68.6	34.5	5,874	75	180.7	90.4	60.2	45.2	2
3	(Schlick)..	1,800	17.80	35.84	61	32	4,605	65	195.4	97.7	65.1	48.9	3
4	(Schlick)..	1,700	16.79	25.99	57	30.8	3,618	70	238.8	119.4	79.6	59.7	4
5	Triple expansion, 3 cranks at 120°.....	2,100	19.62	29.22	61	35.3	3,965	65	258	129	86	64.5	5
6	Quadruple expansion, 4 cranks (Schlick)..	2,750	25.57	21.30	68.6	34.5	5,994	75	179	89.5	59.7	44.8	6
7	Triple expansion, 4 cranks at 90°.....	4,333	12.12	30.60	47.5	33.2	2,120	115	465.5	232.8	155.2	116.4	7
8	Quadruple expansion, 4 cranks (Schlick)..	2,500	27.20	18.35	65	34.2	5,168	75	205.8	102.9	68.6	51.5	8
9	Triple expansion, 3 cranks at 120°.....	3,700	30.46	37.30	70	39.4	5,566	74	197.8	98.9	65.9	49.5	9
10	Do. do.	1,600	12.59	22.52	61	30.2	3,990	72	226.9	113.4	75.6	56.7	10
11	Do. do.	2,400	19.40	48.06	61	34	3,857	72	223.4	111.7	74.5	55.8	11
12	Quadruple expansion, 4 cranks (Schlick)..	1,800	13.88	14.60	46	26.4	3,105	118	277.5	138.7	92.5	69.4	12
13	Triple expansion, 3 cranks at 120°.....	1,500	12.44	32.51	53.5	31	3,291	70	284.3	142.1	94.8	71.1	13
14	Do. do.	1,600	11.04	31.68	53.5	30	3,800	70	257.4	128.7	85.8	64.4	14
15	Do. do.	2,000	19.60	37.90	61	34.8	3,658	66	248.8	124.4	82.9	62.2	15
16	Do. do.	800	87.45	22.15	50	25.5	3,208	75	249.7	124.8	83.2	62.4	16
17	Quadruple expansion, 4 cranks (Schlick)..	3,850	46.78	39.90	70	41	4,986	75	199.6	99.8	66.5	49.9	17
18	Triple expansion, 3 cranks at 120°.....	2,250	17.26	27.04	61	34.6	3,413	76	281.8	140.9	93.9	70.5	18
19	Do. do.	5,667	14	32.20	50	{36* 18†}	2,499	120	437.4	218.7	145.8	109.3	19
20	Do. do.	2,600	18.86	32.32	65	36	3,201	74	278	139	92.7	69.5	20
21	Do. do.	1,400	10.93	20.34	49.5	28	3,008	78	294.8	147.4	98.3	73.7	21

* Outer. † Inner; hollow.

On m_1 is acting a force P which is subject to periodical variations, and whose changes are represented by the curve of crank effort derived from the indicator diagram, taking into account the reciprocating masses. It is evident that the masses m_1 and m_2 will start moving when the force P is acting, and when steady motion is obtained we shall have an average force P_m, an average resistance W_m, and, as a result, for both masses also a corresponding average velocity v_m.

This connection facilitates the solution of the problem, as we may now altogether neglect the advancing (in reality turning) motion, and, instead of the average quantities, substitute zero positions.

We find that the force resistance and the force oscillations now take place to both sides from these positions. The force P is, as we know, given as a periodical function of the crank positions. In order to enable us to carry out the following calculation we shall assume that the crank positions also give corresponding intervals of time. This error is very small when dealing with small variations of the speed of turning. When the variations become greater, as in the vicinity of the critical speeds, the error, of course, may be noticed. But we are obliged to proceed in this manner in order to obtain a result.

Thus we have $P=f(t)$, or considering that we have to deal with a periodical function

$$P=P_1\sin(yt+a_1)+P_2\sin(2yt+a_2)+P_3\sin(3yt+a_3)+\ \ldots$$

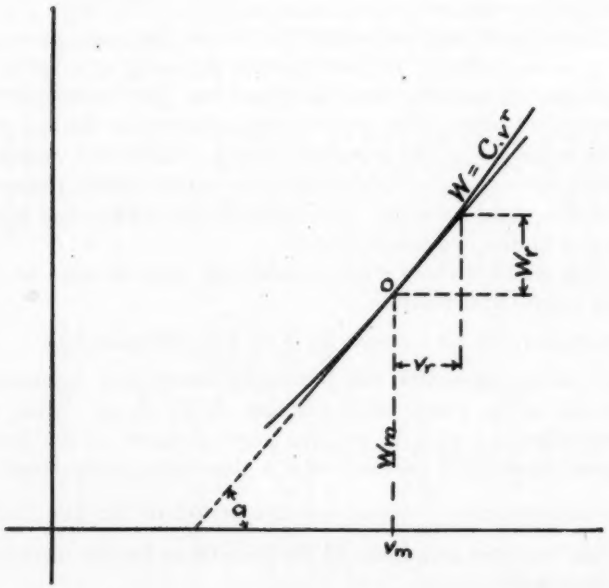
The series represents the previously mentioned harmonical analysis of the crank effort diagram, P_1, P_2, P_3, etc., being the amplitudes and a_1, a_2, a_3, etc., the angular phases of the fundamental harmonical curves. y is a time factor, determined by the equation $y=\frac{2\pi}{t_1}$ where t_1 is the period of the first fundamental vibration and equal to the time taken by one revolution of the engine.

Instead of using t_1, we may introduce the number of revolutions of the engine per minute, n; the equation for y then becomes

$$y=\frac{2n\pi}{60}=\frac{n\pi}{30}\ \ldots\ldots\ldots\ (4a)$$

The irregular force P being split up into a series of harmonical curves (*i. e.*, force oscillations following laws of sines), we can also consider the real motion of the two masses m_1 and m_2 as built up by a series of elementary harmonical motions, which correspond to the individual force oscillations. The problem is solved as soon as we have determined these elementary motions, which correspond to the given harmonical force oscillations.

Figure: 11.



For each of these elementary motions, we may now write down these two differential equations given, which hold for the I order:

$$P_1 \sin \gamma t - m_1 \frac{d^2 s_1}{dt^2} - (s_1 - s_2) c = 0 \quad . \quad . \quad . \quad (5)$$

$$(s_1 - s_2) c - m_2 \frac{d^2 s_2}{dt^2} - k \frac{ds_2}{dt} = 0 \quad . \quad . \quad . \quad . \quad (6)$$

where s_1 and s_2 mean the space traversed by the masses m_1 and m_2 reckoned from their respective zero positions. c is the factor of elasticity of the medium connecting the two masses, in our case the shafting, *i. e.*, the force necessary to make the two masses m_1 and m_2 approach on another by unit distance in their direction of motion. c may be calculated from $c = \frac{GI_p}{R^2 L}$. G, I_p, R and L are known, k is the so-called coefficient of extinction for the mass m_2. It may be derived from the law of resistance of the propeller in the following manner:

According to the relation $W = Cv^r$, we have a definite value W_m (see Fig. 11), corresponding to the value v_m. As we have agreed to consider v_m and W_m as zero values, we shall have to introduce the resistances and velocities into our calculation reckoned only in relation to these zero values. Let us denote these by W_r and v_r. The extinction coefficient k then represents the relative resistance corresponding to the relative velocity $= 1$ and thus becomes $= \frac{W_r}{v_r}$. Assuming that the oscillations are not too great, this value remains constant and equal to tan α where α denotes the angle which the tangent to the W curve at 0 makes with the axis of abscissae. We now have

$$\tan \alpha = \frac{dW}{dv} = r \times C v_m^{r-1}, \text{ and as } C = \frac{W_m}{v_m^r},$$

we may write,

$$k = \tan \alpha = r \frac{W_m v_m^{r-1}}{v_m^r} = r \frac{W_m}{v_m} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Thus we know the constants in the differential equations (5) and (6), and may proceed to solve them.

It is evident that the abscissae of the masses m_1 and m_2 must take the form

$$s_1 = C_1 \sin (\gamma t + \varphi_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$s_2 = C_2 \sin (\gamma t + \varphi_2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

which express that the two masses perform oscillating movements with amplitudes C_1 and C_2 and phase angles φ_1 and φ_2. The introduction of the quantity yt means that both masses oscillate with the same period as the moving force P. Now we have to determine the values of C_1, C_2 and φ_1 and φ_2. For this purpose we derive the following relations:

$$\left.\begin{aligned} \frac{ds_1}{dt} &= C_1 y \cos(yt+\varphi_1) \\ \frac{d^2s_1}{dt^2} &= -C_1 y^2 \sin(yt+\varphi_1) \end{aligned}\right\} \quad . \quad . \quad . \quad (10)$$

$$\left.\begin{aligned} \frac{ds_2}{dt} &= C_2 y \cos(yt+\varphi_2) \\ \frac{d^2s_2}{dt^2} &= -C_2 y^2 \sin(yt+\varphi_2) \end{aligned}\right\} \quad . \quad . \quad . \quad (11)$$

and introduce them into the differential equations (5) and (6). Arranging according to sin yt and cos yt, we obtain:

$$\sin yt\,(P_1 + m_1C_1y^2\cos\varphi_1 - cC_1\cos\varphi_1 + cC_2\cos\varphi_2) + \cos yt\,(m_1C_1y^2\sin\varphi_1 - cC_1\sin\varphi_1 + cC_2\sin\varphi_2) = 0$$

and

$$\sin yt\,(m_2C_2y^2\cos\varphi_2 + kC_2y\sin\varphi_2 + cC_1\cos\varphi_1 - cC_2\cos\varphi_2) + \cos yt\,(m_2C_2y^2\sin\varphi_2 - kC_2y\cos\varphi_2 + cC_1\sin\varphi_1 - cC_2\sin\varphi_2) = 0.$$

These equations will only hold for all values of yt, if the factors of sin yt and cos yt vanish independently.

$$P_1 + m_1C_1y^2\cos\varphi_1 - cC_1\cos\varphi_1 + cC_2\cos\varphi_2 = 0$$

$$m_1C_1y^2\sin\varphi_1 - cC_1\sin\varphi_1 + cC_2\sin\varphi_2 = 0$$

$$m_2C_2y^2\cos\varphi_2 + kC_2y\sin\varphi_2 + cC_1\cos\varphi_1 - cC_2\cos\varphi_2 = 0$$

$$m_2C_2y^2\sin\varphi_2 - kC_2y\cos\varphi_2 + cC_1\sin\varphi_1 - cC_2\sin\varphi_2 = 0$$

which determine C_1, C_2 and φ_1 and φ_2; we obtain the following values:

$$\left.\begin{aligned} \tan\varphi_1 &= \frac{kyc^2}{k^2y^2(m_1y^2-c)+(m_2y^2-c)^2(m_1y^2-c)-c^2(m_2y^2-c)} \\ &= \frac{kc^2}{k^2y(m_1y^2-c)+(m_2y^2-c)\,y\,[m_1m_2y^2-c(m_1+m_2)]} \end{aligned}\right\} \quad (12)$$

$$\tan \varphi_2 = \frac{ky\,(m_1 y^2 - c)}{(m_1 y^2 - c)(m_2 y^2 - c) - c^2} = \frac{k\,(m_1 y^2 - c)}{y\,[m_1 m_2 y^2 - c\,(m_1 + m_2)]} \quad (13)$$

$$C_1 = -\frac{P \sin \varphi_2}{(m_1 y^2 - c) \sin (\varphi_2 - \varphi_1)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

$$C_2 = \frac{P \sin \varphi_1}{c \sin (\varphi_2 - \varphi_1)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

which on introduction in the equations (8 and 9) give the law of motion of the masses m_1 and m_2. Their laws of velocity are formed by introducing the above values into equations (10 and 11.)

Now we are able to trace the positions and velocities of the two masses, measured from an axis of abscissae of time. We may repeat this for all the individual motions corresponding to the various fundamental curves of the turning force diagram and combining the results in the manner shown above, we finally obtain the resultant law of motion of the two masses.

Before considering the practical application of the method, we may find the important law, governing the relative motion of the masses m_1 and m_2. Concerning the distance between the masses, we have the equation (compare Fig. 14).

$$s_1 - s_2 = s_r = C_r \sin (yt + \varphi_r) \quad . \quad . \quad . \quad . \quad (16)$$

where C_r denotes the length of the line $(\overline{A\,B})$ connecting the ends of C_1 and C_2, and $yt + \varphi_r$ is the angle, which this line makes with the axis of abscissae.

For C_r and φ_r we have the following values:

$$\tan \varphi_r = \frac{C_1 \sin \varphi_1 - C_2 \sin \varphi_2}{C_1 \cos \varphi_1 - C_2 \cos \varphi_2} = \frac{m_1 yck}{m_2 y^2 [y^2 m_1 m_2 - c\,(m_1 + m_2)] + k^2 (m_1 y^2 - c)} \quad . \quad (17)$$

$$\text{and} \quad C_r = \frac{C_1 \sin \varphi_1 - C_2 \sin \varphi_2}{\sin \varphi_r} = -\frac{P}{\sin \varphi_r} \times \frac{m_1 yck}{k^2 (m_1 y^2 - c)^2 + y^2 [y^2 m_1 m_2 - c\,(m_1 + m_2)]^2} \quad . \quad . \quad (18)$$

$$\text{and } C_r = \frac{C_1 \cos \varphi_1 - C_2 \cos \varphi_2}{\cos \varphi_r} = -\frac{P}{\cos \varphi_r} \times$$

$$\frac{k^2 (m_1 y^2 - c) + m_2 y^2 [y^2 m_1 m_2 - c (m_1 + m_2)]}{k^2 (m_1 y^2 - c)^2 + y^2 [y^2 m_1 m_2 - c (m_1 + m_2)]^2} \quad . \quad (19)$$

It is of interest to know the relative motion of the masses to one another, which may be represented as the projection (on the axis of ordinates) of the rotary movement of a radius vector $\overline{OE} = C_r$ and parallel to $(\overline{AB})$ (see Fig. 14). The importance hereof arises from the fact that the quantity $s_r = s_1 - s_2$ represents the fraction of the transmitted turning force, which is due to the torsional vibrations of the shaft. The calculations of C_r and φ_r from the equations (17, 18 and 19) at first sight appear rather complicated, yet, in reality, this is not the case, as the same values continually reappear, viz: $(m_1 y^2 - c)$ and $[y^2 m_1 m_2 - c (m_1 + m_2)]$.

This latter expression is of importance, because, when put equal to zero and solved with regard to y, makes equation (4*a*) $n = \frac{30y}{\pi}$ identical with equation (3), which gives the natural number of vibrations of the shaft per minute.

$$y^2 m_1 m_2 - c (m_1 + m_2) = 0$$

$$y = \sqrt{\frac{c (m_1 + m_2)}{m_1 \cdot m_2}} \text{ or, as } c = \frac{G \cdot I_p}{R^2 L}$$

$$y = \frac{1}{R} \sqrt{\frac{G I_p (m_1 + m_2)}{L m_1 \cdot m_2}} = \frac{n\pi}{30}; \quad n = \frac{30}{\pi R} \sqrt{\frac{G \cdot I_p (m_1 + m_2)}{L m_1 m_2}}$$

Thus without knowing it we have struck the case of synchronism between the force oscillations and the individual period of the shafting. In this case the equations (17, 18 and 19) assume a simpler form and become

$$\left.\begin{aligned} \tan \varphi r_o &= y \frac{m_2}{k} \\ \text{and} \qquad Cr_o &= -\frac{P m_2}{k c m_1} \cdot \sqrt{m_2^2 y^2 + k^2} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (20)$$

FIGS. 12—A, B, C, S. S. "BESOEKI."
Twisting of shafts determined theoretically beforehand, revolutions, 83.

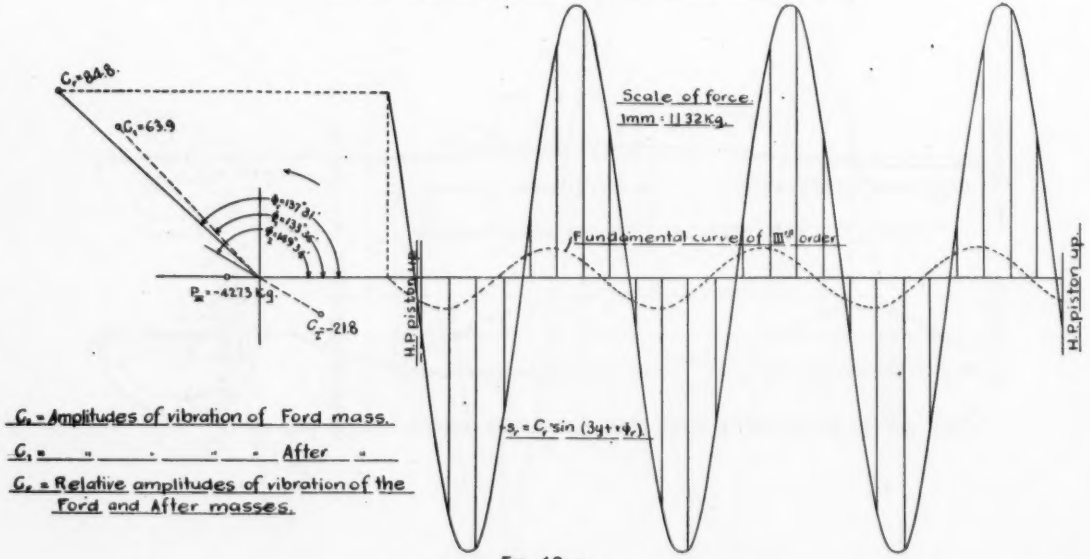

C₁=84.8
aC₁=63.9
φ₁=137° 31'
φ₂=133° 36'
φ₃=149° 34'
P_m=-4273 Kg.
C₂=218
Scale of force.
1mm = 1132 Kg.
Fundamental curve of IIIrd order
H.P piston up
H.P piston up
s_r = C_r sin (3γt + φ_r)
C_r = Amplitudes of vibration of Ford mass.
C_r = " " " " After "
C_r = Relative amplitudes of vibration of the Ford and After masses.

FIG. 12—A.
Twisting caused by the fundamental curve of the IIId order.

Twisting caused by the fundamental curve of IInd order
Fundamental curve of IInd order
Scale of force: 1mm = 1132 Kg.
H.P. piston up
$\vartheta_2 = C_2 \sin(2\psi + \phi_2)$
Twisting caused by the fundamental curve of Ist order
Fundamental curve of Ist order
Scale of force: 1mm = 1132 Kg.
H.P. piston up
$\vartheta_1 = C_1 \sin(\psi + \phi_1)$

FIG. 12–8.

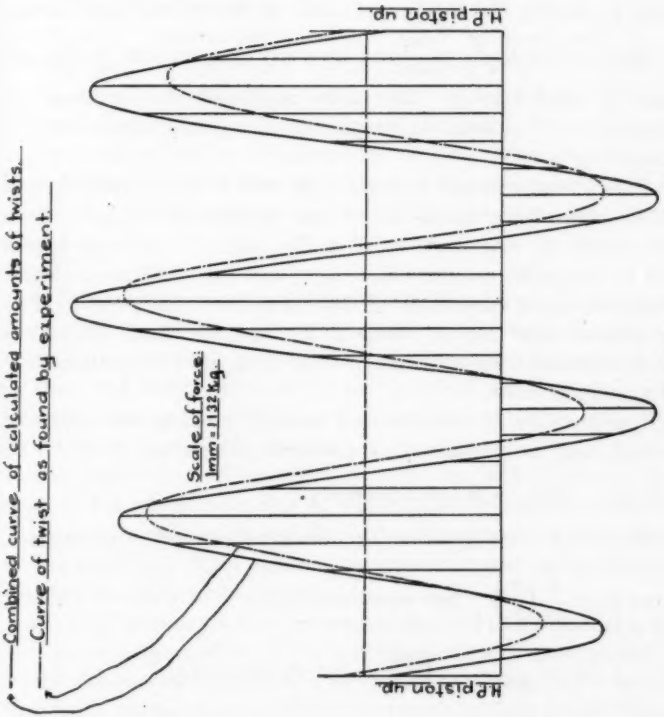

H.P. piston up.
Scale of force:
1mm = 1132 kg.
H.P. piston up.
Combined curve of calculated amounts of twists.
Curve of twist as found by experiment.

FIG. 12–c.

or as k in our case is small as compared to $m_2 y$ and hence may be neglected.

$$Cr_o \simeq -\frac{Pm_2^2}{kcm_1}\, y \simeq -\frac{P}{k}\left(\frac{m_2}{m_1}\right)^{\frac{3}{2}} \sqrt{\frac{(m_1+m_2)}{c}} \quad . \quad . \quad (21)$$

Cr_o which is the amplitude for the case of synchronism, is then a quantity directly proportional to the force P, also to the $\frac{3}{2}$ power of the fraction $\frac{m_2}{m_1}$ and inversely proportional to the extinction coefficient k. The phase angle φr_o lies very near 90 degrees, as k is small in proportion to $m_2 y$ and hence tan φr_o large.

Purely mathematical investigations which would take up too much space here, go to show, that strictly speaking, C_r does not attain its maximum value in the case of synchronism, but for a somewhat smaller value of y, and this difference chiefly depends on the magnitude of the extinction coefficient k. The maximum itself hardly varies at all, and the small differences just mentioned are so small in our cases, that in practice one may neglect them.

For the sake of completeness we may consider the relations which hold for the case of synchronism, *i. e.*, when

$y^2 m_1 m_2 - c(m_1 + m_2) = 0$ becomes

tan $\varphi_2 = \infty$. See equation (13); in consequence $\varphi_2 = 90$ degrees.

tan $\varphi_1 = \frac{c}{ky}\left(\frac{m_2}{m_1}\right)$. See equation (12).

$$C_1 = -\frac{P}{ky \sin \varphi_1}\left(\frac{m_2}{m_1}\right)^2. \quad \text{See equation (14).}$$

$$C_2 = \frac{P}{ky}\left(\frac{m_2}{m_1}\right). \quad \text{See equation (15).}$$

Another interesting special case is $m_1 y^2 - c = 0$ when C_r is given by the simple expression $\frac{P}{c}\left(\frac{m_2}{m_1}\right)$. The equations (12, 13, 14, 15, 17, 18, 19), also take simple forms, when for instance c

$= \infty$, *i. e.*, the shafting absolutely rigid, which holds approximately for the large engines of fast liners, or $m_1 = m_2$, but the complete treatment of these cases would carry us beyond the limits of this investigation.

So far we have only considered the behavior of the two masses. Now we shall proceed to investigate the movement of the individual cross sections of the shafting. From Fig. 14 we see that any point F between the masses m_1 and m_2 corresponds to a definite cross section, which divides the total length of shafting in the same proportion as F does with regard to the distance s_r between m_1 and m_2. The motion of the point F or the cross section may again be considered as the projection (on the axis of ordinates) of the rotary movement of the radius vector $\overline{O F_1}$ whose end F_1 lies on the line $\overline{A B}$ dividing this in the proportion $\frac{Fm_1}{Fm_2}$ as well.

In this manner one may determine the movement of any cross section of the shafting. As the length of the radius vector indicates the amplitude of oscillation of the section in question, it follows, that where the radius vector is a minimum we shall also find the smallest amplitudes. This radius vector we may find by dropping a perpendicular from O on $\overline{A B}$.

The intersection D_1 of this perpendicular with $\overline{A B}$ and the point of the intersection D of $m_1 m_2$ with a horizontal line through D_1, then give the position of the section of minimum oscillation in the shafting. This section consequently also possesses the smallest variations of velocity.

We shall now apply this theoretical method to a practical case, viz: to the engine of the *Besoeki* at the number of revolutions at which the measurements were carried out. These latter would then form an excellent criterion of the correctness of the theoretical deductions.

The relative amounts of twist of the shafting have been drawn in Fig. 12–A, B, C, where the A curve shows twisting of the IIId order, the 12–B curve for the second order, below this comes one of the first order, and finally 12–C, the lowest curve, drawn in full, shows the resultant of the three curves.

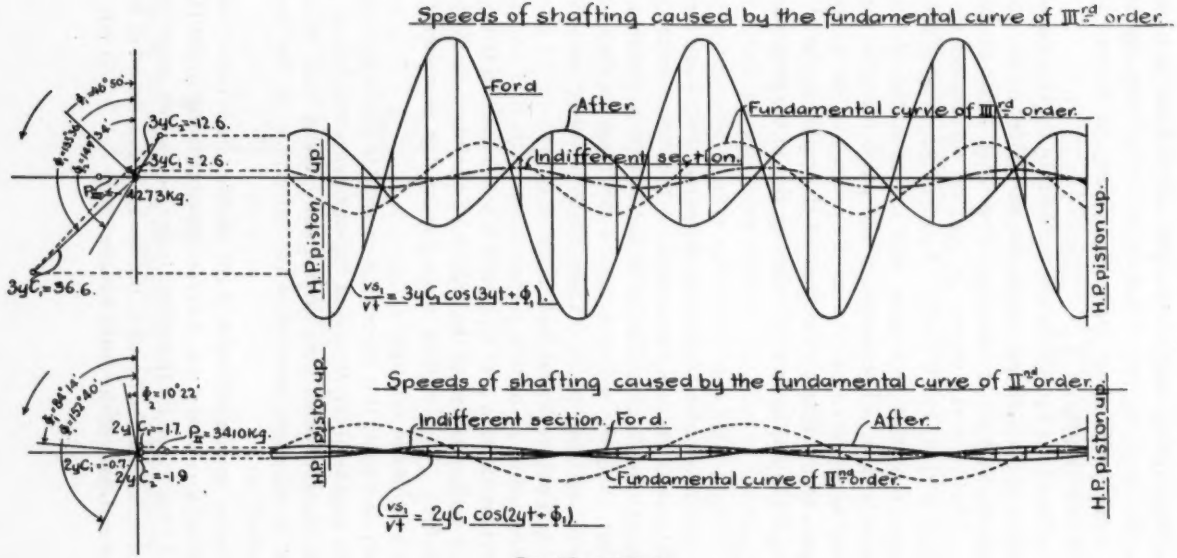


FIG. 13—A AND B.

Speeds of turning determined theoretically beforehand, revolutions, 83.
Scale: 1 mm. = .0527 m/sec. Tangential speed at crank radius.

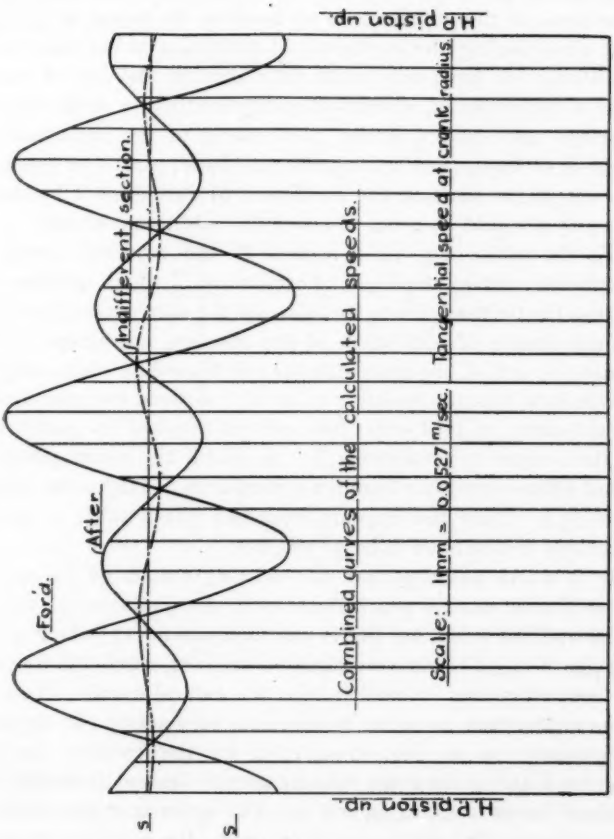

H.P piston up
Indifferent section.
After
Ford.
Combined curves of the calculated speeds.
Scale: 1mm = 0.0527 m/sec. Tangential speed at crank radius.
H.P piston up
S
S

FIG. 13–B.

Comparing this with the experimental curve, also shown by a dotted line, we find good coincidence as regards phases, and a fair coincidence as regards amplitudes. The actual amplitudes are smaller than the calculated ones by about 20 to 25 per cent. The cause of this difference is probably to be found in the fact that when finding the coefficient of extinction in the theoretical calculation we have only taken into account the law of resistance of the propeller, whereas in reality the friction in the various bearings and stuffing boxes, particularly in the reciprocating parts, is of importance as regards extinction, too. For this reason one might increase the coefficient of extinction k by about 20 to 25 per cent. in order to cover this additional action.

To the left in Fig. 12–A, B, next to the twisting curves, is shown the relative amplitude of oscillation C_r which enables one to draw the twisting curves, and also, for the sake of completeness, the amplitudes of oscillation of the absolute movement of the masses m_1 and m_2, together with the corresponding phase angles.

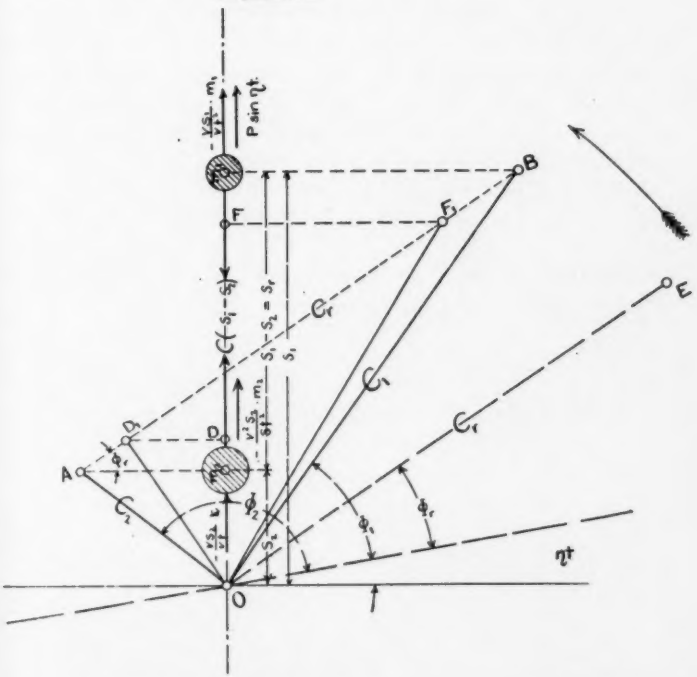
One finds that the resulting value of C_r derived from the fundamental curve of IIId order has not yet reached its maximum, as the number of revolutions (83) on which the investigation is based differs somewhat from the critical ones of IIId order, which were 85.8. This also appears from the phase angle φ_r which otherwise would have to be 90 degrees.

It is worth noticing that the twisting curves of Ist or IId order almost exactly synchronize with the fundamental curves of Ist and IId order, but this is due to equation (17) which gives the phase angle either very nearly 0 degrees, when the number of force vibrations is smaller than the natural number of vibrations of the shaft, or in the reverse case very nearly 180 degrees.

Similarly, as in Fig. 12–A, B, C, for the twisting curves, Fig. 13–A and B show the velocity curves derived from the calculated values of C_1, C_2, φ_1 and φ_2. The uppermost set of curves on A shows the velocities of IIId order, the next one those of IId order, and the ones on B, the resulting velocities. The curves of Ist order have been left away, as their amplitudes were so small that one could scarcely represent them graphically. A comparison of the resulting constructed curves with the ones derived by

experiment again shows good coincidence, as regards phases, whilst the amplitudes themselves, as in the case of the twisting curves, become too great. We would in this case also have obtained closer coincidence by assuming the value of k to be 25 per cent. greater.

Figure 14.

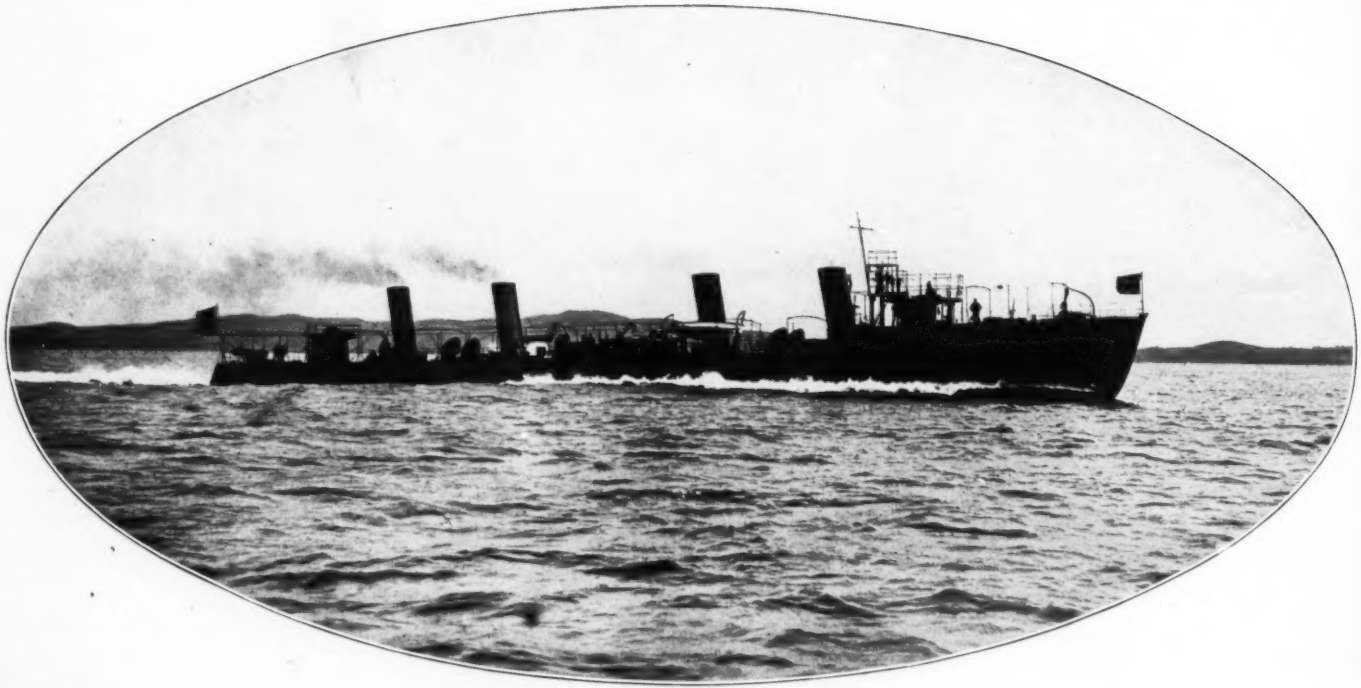


Attention is called to the velocity curve of the *indifferent cross section*, whose position is found in the manner described above by means of a special diagram shown to the left of the upper set of curves. In the present case this section, practically speaking, coincides with the common center of gravity of the masses m_1 and m_2. This also shows that the greater oscillations of the shafting leave the center of gravity approximately at rest.

The theoretical method for analyzing the dynamical actions in long shafts as given above is of special importance as it enables us to determine these actions in any given case beforehand. It is to be hoped that the many erroneous notions as to the nature of the turning forces transmitted through shafting will now be superseded by correct ones.

Concluding, I may point out that the above does not represent the complete result of the experiments. A great many of these could not be embodied in this paper, partly for business reasons, partly on account of limit of space. For these reasons also, I have had to abstain from enumerating several other conclusions arrived at.

I hope that I have treated the problem, which had been given me to solve, in a comparatively exhaustive manner, still I shall be very glad if other parties would repeat or supplement my experiments, as there are special cases, whose experimental solution would be of great interest.



THE "PERRY" AT 28.5 KNOTS.

CONTRACT TRIALS OF TORPEDO-BOAT DESTROYERS *PAUL JONES, PERRY* AND *PREBLE.*

By Leo Morgan, Associate.

The *Paul Jones*, *Perry* and *Preble* are twin-screw torpedo-boat destroyers of about 420 tons displacement, and were built by the Union Iron Works, of San Francisco, Cal., from the same general plans and specifications furnished by the Navy Department.

The contract for these boats was signed on October 5th, 1898, the price, exclusive of ordnance, ordnance stores and a few other articles furnished by the Government, being $285,000 each, and the time allowed for completion eighteen months. Owing principally to the delay in procuring material, this time was extended to April 5th, 1900, and was again extended, on account of a strike, to January 13th, 1901.

The guaranteed speed was 29 knots, to be maintained for two consecutive hours, the vessels to be weighted to a displacement of 420 tons. A premium for an excess of speed over that required by the contract was not offered, but it was stipulated that a penalty, at the rate of $32,000 per knot, was to be exacted in case the speed fell below 28 knots.

The weight of the machinery was limited to 198 tons, exclusive of stores and spare parts supplied by the Government, steam steering gear, steam windlass, dynamo and engine, and torpedo air-compressor machinery.

The penalty for overweight of machinery was $200 per ton in excess of 198 tons. If this weight exceeded 5 per cent. of the contract weight a further reducing of $1,000 was to be made from the contract price.

The first progressive speed trials of the *Perry* were made under the original speed requirements, while the latter trials of the three

boats were made under the modified condition as to limit of speed and duration of trial.

HULL.

The hull is constructed of mild steel of domestic manufacture, with frames spaced 21 inches apart throughout. The keel plate is 12½ pounds, vertical keel is 10 pounds, sheer strake is 12½ pounds (nickel-steel), and all other shell plating is 9 pounds, except garboard strake, which is 10 pounds.

The ship is divided into thirty-seven watertight compartments. The main and forecastle decks are partially covered with rubber and steel matting.

Hold.—In the hold forward of engine and boiler compartments are reserve feed-water tanks, reserve coal, magazine, torpedo war heads, stores and fresh-water tanks. In the hold aft of engine and boiler compartments are reserve feed-water tanks, stores and magazines.

Forward Platform.—On forward platform are windlass room and stores.

Berth Deck.—On forward berth deck are crew's wash room, crew's quarters and crew's water closets. On after berth deck are wash room, lavatory, and showers and water closets, petty officers' quarters and galley, commander and chief engineer's staterooms, wardroom, dining room, wardroom pantry, navigator's office and dispensary.

Coal Bunkers.—There are eight coal bunkers, four on the starboard side with a capacity of 89.32 tons, and four on the port side with a capacity of 89.32 tons, making a total of 178.76 tons at 43 cubic feet to the ton. Reserve coal bunker capacity is 23.4 tons, making a grand total of 202.16 tons. The bunkers are filled from coal scuttles in main deck direct to bunkers.

HULL DATA—*PERRY.*

Length over all, feet	250
on L.W.L., feet	244
Beam, extreme, feet and inches	23-6
Ratio of length to beam	9.63
Depth (midship frame at side), feet and inches	14-3
Draught, forward, sea-going trim, feet and inches	5-10
aft, sea-going trim, feet and inches	8-2
mean, sea-going trim, feet	7

Displacement, sea-going trim, tons	470
per inch at L.W.L., tons	9
Area of immersed midship section (L.W.L.), square feet	126.7
Center of gravity of L.W.L. plane, aft midship section, No. 71, feet	7.5
Center of buoyancy above bottom of keel, feet	4.6
forward of midship section, No. 71, feet	3.5
gravity above bottom of keel, feet	9.4
Transverse metacenter above center of buoyancy, feet	8.9
Longitudinal metacenter above center of buoyancy, feet	788.
Coefficient of fineness	.41
of midship section	.77
of L.W.L.	.72
Cylindrical coefficient	.53
Number of frames	140
watertight compartments	37

Main Drains.—In each engine compartment there is a 7-inch main drain which also drains the adjoining boiler compartment. Each drain pipe has a 7-inch connection to the circulating pump in its compartment. The main drain valves are fitted with suction boxes, and both engine and boiler compartment valves are operated from the engine-room floor. There is no connection between the two main drains.

Auxiliary Drains.—This system extends from just forward of bulkhead No. 18, the after bulkhead in compartment A 2, to between frames Nos. 134 and 135, in compartment D 6. From bulkhead No. 18 aft to "cut-out" valve A, between frames No. 47 and No. 48 in the forward boiler compartment, the drain pipe is 2 inches in diameter. From this cut-out valve to the 3-inch drain valve between frames Nos. 92 and 93 in the after boiler compartment the drain pipe is 3 inches in diameter; from this point aft the drain pipe is 2 inches in diameter, with a cut-out valve (B) between frames Nos. 98 and 99 in the after boiler compartment. The forward compartment, A 1, drains into compartment A 2, through a sluice gate at bulkhead No. 7. The after compartment, D 7, drains into compartment D 6 through a sluice gate at bulkhead No. 136; all other compartments are fitted with suction boxes and drain valves. All drain valves forward of cut-out valve A, between frames Nos. 47 and 48, are operated from the berth deck, while all drain valves aft

of this point, excepting the cut-out valves in the boiler compartments, which are operated from the fire-room floors, are operated from the main deck.

The boats carried are as follows:

One 20-foot whale boat on starboard side.
Two 20-foot cutters on port side.
Two 18-foot folding boats.

ARMAMENT.

Five 6-pounder, semi-automatic guns.
Two 3-pounder, 50-caliber, rapid-fire guns.
Ten 6-millimeter rifles.
Seventy-two 38-caliber revolvers.
One 45-caliber rifle.
One 22-caliber rifle.
Two long torpedo tubes, Whitehead.
Four 5-meter torpedoes, Whitehead.
Four torpedo war heads, Whitehead.

MAIN ENGINES.

There are two vertical, inverted, direct-acting, triple-expansion engines placed abaft each other in separate watertight compartments. Each engine is directly connected to its corresponding propeller and is independently operated.

Each engine has four cylinders; the order from forward in the forward engine is: 2d low pressure, intermediate, high and 1st low pressure; for the after engine, 1st low pressure, high, intermediate and 2d low pressure. None of the cylinders are jacketed, but all are clothed with non-conducting material.

The valves for all cylinders are of the double-ported piston type, there being one for the H.P., two for the I.P., and two for each of the L.P. cylinders of each main engine. For ease in overhauling, the diameter of the upper piston-valve head is $\frac{1}{32}$ of an inch larger than the lower. Neither balance piston nor starting valves are fitted, but provision for starting the engines is made by admitting live steam to the 2d receivers. The valve gear is of the Stephenson double-bar link type. Independent cut-offs are not fitted, but a variation in the cut-off of each

cylinder, ranging from .5 to .7 of the stroke, is obtained by means of an adjustable block fitted in a slot in the reverse-shaft arm and actuated by a hand wheel and screw.

The main pistons are of dished form, the high pressure being of cast iron, the intermediate and low-pressure pistons are forged steel. Each piston is fitted with two cast-iron packing rings $\frac{1}{2}$ inch wide by $\frac{9}{16}$ inch thick.

The piston rods, connecting rods and valve stems are of high grade nickel-steel. The crossheads are forged on the piston rods and are fitted with manganese-bronze slippers, the sliding parts of which are faced with Finn's-Parson's metal.

The crosshead guides are of cast iron, and are cast hollow for water circulation. They are secured at the tops to feet cast on the cylinder casings, and at the bottoms to a cast-steel girder bolted to the engine framing. The backing guides are of forged steel and bolted to flanges for that purpose on the go-ahead guides.

The eccentrics are of cast iron, each in two parts, bolted together by fitted bolts and secured in position by a $\frac{7}{8}$ set screw and feather key fitted with adjustable side pieces to provide for a limited amount of adjustment. The eccentric straps are of composition lined with white metal, and the eccentric rods are of nickel-steel. The links are of nickel-steel and of the Stephenson double-bar type.

The H.P. valve stems are fitted with cast-steel crossheads faced with composition gibs. The I.P. and L.P. valve stems have cast-steel yokes fitted with composition gibs working in cast-steel guides.

Each bedplate consists of six independent cast-steel main-bearing girders, securely bolted to the engine seatings. The main bearings and caps are of composition, cast hollow for water circulation and lined with white metal.

The reversing engine consists of a steam cylinder and an hydraulic controlling cylinder, attached directly to two arms keyed to the reverse shaft. The by-pass valve on the controlling cylinder is attached to a prolongation of the steam valve stem, and both valves are operated by a system of differential levers,

the primary motion of which is obtained from a hand lever at the working platform, while the secondary motion is derived from a pin in the reversing engine crosshead.

For reversing by hand, a hand pump with the necessary stop-cock, pipes and fittings is attached to the controlling cylinder.

For turning the engines, a worm wheel with a ratchet lever is fitted to the forward end of each crank shaft.

Each engine has an 8-inch unbalanced throttle valve of the conical type, fitted with a vertical screwed stem which is operated through a toggle joint with suitable shafting and gearing, and hand wheel at the working platform.

For warming up and slow running, a $1\frac{1}{2}$-inch by-pass or auxiliary throttle is fitted to the main throttle casing.

The main and auxiliary steam lines in the engine and boiler rooms are of lap-welded steel with the flanges welded on. In the boiler rooms the main steam pipes are $6\frac{1}{2}$ inches outside diameter and 5.9 inches inside diameter. In the engine rooms the main steam line is $8\frac{5}{8}$ inches outside diameter and 7.875 inches inside diameter.

The auxiliary steam line throughout is 4 inches outside and 3.524 inches inside diameter.

The oil, waste and tallow tanks are located in the forward engine room. There are two main oil tanks of about 300 gallons total capacity, fitted with filling pipes from deck; one 20-gallon oil tank, and one 100-pound waste tank, and one tallow tank of about the same capacity.

ENGINE DATA.

Cylinders, number for each engine	4
diameter of H.P., inches	$20\frac{1}{2}$
I.P., inches	32
L.P., (2), inches	38
Stroke of pistons, inches	22
Valves, diameter of H.P. (one for each engine), inches, top	12
bottom	$11\frac{11}{32}$
I.P. (two for each engine), inches, top	12
bottom	$11\frac{11}{32}$
L.P. (two for each engine), inches, top	13
bottom	$12\frac{11}{32}$

Valve stems, H.P. (1), diameter, inches	1⅝
through valve, inches	1¼ and 1⅛
I.P. (2), diameter, inches	1⅝
through valve, inches	1¼ and 1⅛
L.P. (4), diameter, inches	1⅝
through valve, inches	1¼ and 1⅛
Main steam pipe, diameter, inches	7⅞
Exhaust pipes to condenser (2), diameter, inches	16
Piston rods, diameter, inches	4¼
length from piston to center of crosshead, feet and inches	3-9¼
axial hole, diameter, inches	2½
Connecting rods, length from center to center, inches	46½
diameter of upper end, inches	3⅞
lower end, inches	4⅛
axial hole, diameter, inches	2¼
crank-pin bolts (2), diameter, inches	2¼
axial hole, diameter, inches	1¼
crosshead pin, length, inches	7¼
diameter, inches	5
axial hole, diameter, inches	3
Crossheads, surface (ahead), square inches	176
(backing), square inches	112
Crosshead pins, diameter, inches	5
length, inches	7¼
axial hole, diameter, inches	2¼
Reversing gear, steam cylinder, diameter, inches	8
stroke, inches	10

Shafting and Bearings.—The crank, thrust, line and propeller shafting is hollow and of forged steel. The crank shaft of each engine is in two sections which are not interchangeable. The cranks of the high-pressure and first low-pressure cylinders are placed opposite each other, as are also the intermediate and second low-pressure cranks. The high and first low-pressure cranks make an angle of 90 degrees with the intermediate and second low-pressure, and the crank sequence is high-pressure, intermediate-pressure, first low-pressure and second low-pressure.

The line shafting on the port side is in two sections, supported on two spring bearings, while on the starboard side the shaft is in three sections and supported on three spring bearings.

The propeller shafts are cased with composition at bearings only. The after casing projects about one inch into the propeller hub, and is made watertight by pumping red-lead putty into the cavity between end of casing and bottom of counter bore in hub.

PERRY.

Cylinders designed $\frac{20\frac{1}{2}+32+38+38}{22}$	Starboard engine.					Port engine.				
	H.P.	I.P.	F.L.P.	A.L.P.	Total L.P.	H.P.	L.P.	F.L.P.	A.L.P.	Total L.P.
Cylinder, diameter	$20\frac{1}{2}$	32	38	38	53.72	Same for port engine.				
Piston rod, area	14.186	14.186	14.186	14.186	28.372					
Area :										
Top end	230.06	804.25	1134.1	1134.1	2268.2					
Bottom end	315.874	790.064	1119.914	1119.914	2239.828					
Average	322.967	797.157	1127.007	1127.007	2254.014					
Ratios, common	1.000	1 : 2.468	1 : 3.525	1 : 3.525	1 : 7.050					
Volume swept by piston :										
Top	7261.32	17693.50	24950.2	24950.2	49900.4					
Bottom	6949.228	17381.408	24638.108	24638.108	49276.216					
Average	7105.274	17537.454	24794.154	24794.154	49588.308					
Ratio of volumes, average,	1.000	1 : 2.468	1 : 3.489	1 : 3.489	1 : 6.978					
Volume of clearance :										
Top	1905.2	3450.1	4143	4018.3	8161.3	1780.5	3325.5	4101.4	4143	8244.4
Bottom	2133.8	4350.8	4905	4918.9	9823.9	2140.5	4337	4765.5	4870.4	9635.9
Average	2019.5	3900.45	4524	4468.6	8992.6	1960	3831.25	4433.45	4506.7	8940.15
Per cent. of clearance :										
Top	26.24	19.49	16.60	16.11	16.36	24.51	18.79	16.438	16.61	16.52
Bottom	30.07	25.04	19.91	19.95	19.93	30.803	24.95	19.33	19.75	19.55
Average	28.15	22.26	18.25	18.03	18.15	27.65	21.87	17.88	18.18	18.03
Volume + clearance :										
Top	9166.52	21143.60	29093.2	28968.5	58061.7	9041.8	21019	29051.60	29093.2	58144.8
Bottom	9083.028	21732.208	29543.108	29657.008	59200.116	9089.728	21718.408	29403.608	29508.508	58912.116
Average	9124.774	21437.904	29318.154	29312.754	58630.908	9065.764	21368.704	29227.604	29300.854	58528.458
Ratio of volumes + clearance	1 : 1.000	1 : 2.494	1 : 3.213	1 : 3.212	1 : 6.425	1 : 1.000	1 : 2.357	1 : 3.213	1 : 3.244	1 : 6.457

The inboard ends of the propeller shafts are attached to the line shafts with forged-steel sleeve couplings secured by feathers and cross keys. The forward ends of the after lengths of the line shafting are fitted with a forged-steel flanged sleeve coupling for securing to the forward length on the port side and the intermediate length on the starboard side. The forward length on the port side and the forward and intermediate lengths of line shafting on the starboard side are fitted with coupling discs, each drilled for eight $1\frac{1}{16}$-inch bolts.

Thrust Bearings.—The thrust bearings are of the collar type, and are made of cast steel. The pedestal is cast hollow and divided longitudinally into three pockets, the central one forming an oil trough, while the wing pockets are fitted for water circulation. The ends of pedestal terminate in white-metalled bearings with caps for supporting the weight of shaft, and are fitted with divided stuffing boxes to prevent the escape of oil. The bottom bearing is cylindrical and turned to fit the pedestal, in which provision is made for end adjustment. The cap is let into the bottom bearing, and is so bolted to the pedestal as to permit longitudinal adjustment. Like the pedestal, the cap is cast hollow, and has two wing pockets which are fitted for water circulation, and a central oil box with cover extending nearly the whole length of bearing. The collar spaces of both bearings and caps are lined with white metal.

Crank shafts, diameter, inches	$8\frac{1}{2}$
axial hole, diameter, inches	$4\frac{1}{4}$
coupling disc, diameter, inches	$15\frac{1}{4}$
thickness, inches	2
bolts in one flange (8), diameter, inches	$1\frac{1}{16}$
journals, diameter, inches	$8\frac{1}{2}$
length, inches	14, 12, 12, 12, 14, 14
length of short section, feet and inches	9–4
long section, feet and inches	9–9½
Crank pins, diameter, inches	$8\frac{1}{2}$
length, inches	12
axial hole, diameter, inches	$4\frac{1}{4}$
Crank webs, width, inches	$10\frac{1}{2}$
thickness, inches	$4\frac{1}{2}$
Thrust shafts, diameter, inches	$7\frac{7}{8}$
of coupling discs, inches	$15\frac{1}{4}$
axial hole, diameter, inches	$4\frac{1}{4}$

Thrust shafts, collars, number, each shaft	11
diameter, inches	11⅝
thickness, inches	1
distance between, inches	1¼
surface, total for both engines, square inches	1,128
length, feet and inches	5–3
Line shafts, diameter, inches	7⅞
axial hole, diameter, inches	4⅝
diameter of coupling discs, inches	15½
total length, feet and inches	105–2
Propeller shafts, diameter, inches	7⅞
axial hole, diameter, inches	4⅝
length, feet and inches	46–4
Stern-bracket bearing, after, length, inches	27
forward, length, inches	20
diameter, inches, after and forward	8⅞
Stern-tube bearing, length, forward, inches	24½
diameter, inches	8⅞

Main Condensers.—There is one condenser for each main engine. The shells, water chests, tube sheets, tube-supporting plates and deflecting plates are of Muntz metal. Each shell is in two sections, flanged and riveted together at the center. Composition flanges are riveted to the outer ends for securing to the water chests. Two cast-composition stiffening rings, terminating in supporting brackets, are riveted to each shell for securing condenser to seatings. The water chests are fitted with composition rings for securing to condenser and circulating pipe, and the forward water chest is fitted with a series of concentric rings for deflecting the entering water over the ends of the tubes. There are no steam-deflecting plates, but a plate 37½ inches long is fitted at each end over the air-pump suctions. All composition fittings to shell and water ends are riveted and soldered at joints. All longitudinal seams in shells and water ends are brazed.

Diameter of shell (inside), feet and inches	4–5½
Thickness of shell, No. 10 B.W.G., inch	.134
Length over heads, feet and inches	9–4½
Tubes, diameter (outside), inch	⅝
length between tube sheets, feet and inches	9–3
thickness, No. 20 B.W.G., inch	.035
number in each condenser	2,292
Cooling surface, each condenser, square feet	3,470
total, square feet	6,940
Ratio of total cooling to total heating surface	2.562

Main Air Pumps.—For each engine there are two vertical, double-acting Bailey air pumps. They are placed at the fronts of the H.P. and I.P. cylinders, and are driven by beams actuated by links swinging from the H.P. and I.P. crossheads. The pump valves are each made of three flat discs, $\frac{1}{32}$ inch thick, of rolled phosphor-bronze.

Diameter of pump cylinders (four), inches	12
Stroke, inches	6
Diameter of pump rods, inches	2
Kind and diameter of pump valves (manganese-bronze), inches	$3\frac{1}{16}$
Ratio of volume swept by L.P. pistons per stroke to that of the two air-pump buckets per stroke	38.8 to 1

Auxiliary Air Pump.—For the purpose of freeing the condensers when the main engines are not moving, a vertical trunk pump is operated from the inboard end of each of the circulating-pump crank shafts.

Diameter of pump, inches	6
trunk, inches	3
Stroke of pump, inches	2

Auxiliary Circulating Pump.—For the purpose of providing circulating water when the speed of the vessel is such as to render the scoop inefficient, a single-opening centrifugal pump of 2,000 gallons capacity per minute is attached to each condenser. The pump draws from the sea, through the main injection pipe, in which a butterfly valve is fitted for the purpose of deflecting the circulating water through the pump when required, and is driven by a vertical, single-cylinder engine, which also drives the auxiliary air pump.

Diameter of steam cylinder, inches	6
Stroke, inches	5
Diameter of pump runner, inches	22
Width of runner, inches	at hub, $2\frac{1}{2}$; at rim, $1\frac{1}{2}$
Diameter of inlet nozzle, inches	7
outlet nozzle, inches	7

Feed-Water Heaters.—In each engine room there is one cylindrical tubular heater, so placed and fitted that the discharge from

the main feed pump in its compartment can be put through the heater or by-passed direct to the main feed line; but the heater in one engine compartment cannot be used in conjunction with the main feed pump in the adjoining compartment.

Inside diameter of heater, inches	16
Length of tubes over all, feet	6
Number of tubes	184
Diameter of tubes, inch	$\frac{5}{8}$
Thickness, No. 16 B.W.G., inch	.065

Screw Propellers.—The propellers are of the modified Griffiths type, three-bladed true screws, bent back six inches at the periphery. They are made of phosphor-bronze, tinned all over, and secured to the shafts by two keys and a composition nut screwed on and locked in place. The port propeller is right-handed and the starboard propeller is left-handed.

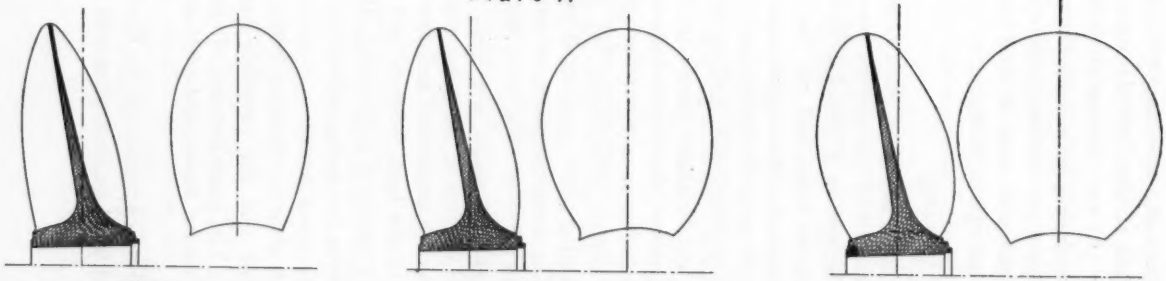
PROPELLERS—(TWIN SCREW).

	Perry. (A)	*Preble.* (B)	*Paul Jones.* (C)
Number of blades	3	3	3
Diameter, feet and inches	7-5	7-5	7-5
hub at center, inches	16	16	16
Length of hub, feet and inches	19-$\frac{5}{8}$	19-$\frac{5}{8}$	19-$\frac{5}{8}$
Pitch, feet and inches, designed	10-10	10-6	10-10
measured	10-10	10-4$\frac{3}{4}$	10-7$\frac{7}{8}$
Greatest width of blade, feet and inches	1-5$\frac{1}{4}$	2-8	3-2$\frac{1}{4}$
Distance from center to greatest width, ft. and in.	2-3	2-4$\frac{1}{2}$	2-3$\frac{3}{4}$
Helicoidal area (3 blades), sq. ft., designed	16.4	20	24
actual	16.83	20.33	24
Projected area, square feet, designed	11.9	15.46	18.6
Disc area, designed	43.20	43.20	43.20
Pitch ÷ diameter, designed	1.461	1.415	1.461
Helicoidal area ÷ disc area, designed	.379	.462	.555
Projected area ÷ disc area, designed	.252	.357	.431
Area of immersed midship section at 6 feet six inches draught, square feet	103.75	103.75	103.75
Center above lowest point of keel, ft. and in.	4-2	4-2	4-2
Weight of one propeller, pounds	1,626	1,829	2,011

Propeller (A) is the screw originally designed for these vessels, and was used on the *Perry* during all of her trials.

PROPELLERS.

Plate A



PERRY
TRIAL SCREW (A)

PREBLE
TRIAL SCREW (B)

SCALE 1 INCH = 1 FOOT

PAUL JONES
TRIAL SCREW (C)

PLATE A.

	PERRY TRIAL SCREW (A)	PREBLE TRIAL SCREW (B)	PAUL JONES TRIAL SCREW (C)
DIAMETER FEET AND INCHES	7-8	7-5	7-5
PITCH DESIGNED	10-10	10-6	10-10
MEASURED MEAN	10-10	10-4.8	10-7¾
HELICOIDAL AREA DESIGNED	18.4 SQ.FT.	20 SQ.FT.	24 SQ.FT.
MEASURED	16.83 " "	20 " "	24 " "
PROJECTED AREA	11.9 " "	15.66 " "	18.6 " "
DISC AREA	43.2 " "	43.2 " "	43.2 " "

Propeller (B) was designed in accordance with the Bureau's instructions, when the trials of the *Perry*, in 1901, established the fact that the propeller (A) was deficient in helicoidal area, and was used on the *Preble* during her official trials.

Propeller (C) was designed at the suggestion of the Trial Board after the *Perry's* successful trials in 1902, and was used on the *Paul Jones* during her official trials.

BOILERS.

There are four Thornycroft boilers of the two-furnace type, designed for a working pressure of 300 pounds per square inch. Two of the boilers are located in a closed compartment just forward of the forward engine room, and two are located in a closed compartment just abaft the after engine room. Owing to space available, the forward boiler in the forward compartment is twelve inches narrower than the other boilers, thereby reducing the width of grates, and to slight extent the tube-heating surface. With these exceptions, the four boilers are duplicates in all particulars. Each boiler consists of one 37-inch steam drum, one 19-inch lower central water drum, two 7½-inch wing drums, with 6½-inch connecting pipes, 1,718 small tubes and fourteen downtake tubes. The small tubes are of seamless, cold-drawn steel, the downtake tubes of mild steel, the wing drums are of solid-drawn steel, and the steam and lower central water drums are lap-welded and of class A, No. 3, boiler plate. There are two furnaces to each boiler, lined front and back, with 2-inch fire brick; the lining, front and back, extends up to the apex of the tubes, at which point a fire-brick arch extends the full length of the furnace. At the sides the lining extends to within about 1 inch of the center of the lower drums.

Each furnace is fitted with two furnace doors, two ash-pit doors, sight and air doors with the necessary operating gear, and a fire extinguisher. The grate bars are of steel, in groups of five and six for the forward boiler, and of three and five for the after boiler.

The boiler casing, in sections convenient for handling, is made of ½-inch magnesia board faced on both sides with light galvan-

ized sheet steel. It is bolted to angle irons on the steam-drum, lower central water-drum and wing-drum seatings, and is fitted with sight and soot doors.

The boilers are bolted to the central seatings and the wing drums rest in chairs bolted to the side seatings. 'Thwartship stays are fitted from the top of the boiler to the deck beams.

Thornycroft automatic feed regulators are fitted to each boiler, and each boiler has a separate smoke pipe.

BOILER DATA.

Steam pressure, designed, pounds	300
at engine, pounds	250
Number of boilers	4
Width over casing, three after boilers, feet and inches	15-9
one forward boiler, feet and inches	14-9
Length over casing, four boilers, feet and inches	9-10½
Height from bottom of ash pan to top of casing, feet and inches	10-4½
Steam drum, diameter, inside, inches	37
length, inside, feet and inches	12-3½
thickness, inch	1
Water drum, diameter, inside, inches	19
length, inside, feet and inches	10-8
thickness, inch	11/16
Wing drums, diameter, inside, inches	7½
length, inside, feet and inches	10-9½
thickness, inch	½
Furnace (1), width grate for one furnace, three after boilers, feet and inches	5-9
width grate for one furnace, one forward boiler, feet and inches	5-3
length of grate, feet	7
number of furnaces to each boiler	2
furnace doors to each boiler	4
Tubes, diameter, inches	1¼, 1½ and 4
number, 1¼-inch	1,346
1½-inch	372
4-inch	14
thickness, 1¼ and 1½-inch tubes	No. 11 B.W.G.
4-inch tubes, inch	5/16
Heating surface, one after boiler, square feet	4,458.22
one forward boiler, square feet	4,408.22
four boilers, square feet	17,833
Grate surface, one after boiler, square feet	80.5

Grate surface, one forward boiler, square feet	73.5
four boilers, square feet	315
Ratio of H. S. to G. S., total	51.8 to 1
Smoke pipes (4), diameter (oval), feet and inches	4-3 x 3
area, each, square feet	10.22
total area of 4 pipes, square feet	40.88
Ratio of pipe area to G. S.	1 : 7.705
Average height above base line, feet	33
Safety valves (2), diameter, inches	3
Combined pressure-reducing and automatic boiler stop valve, in.	5¾
Main-boiler stop valve, diameter, inches	5¾
Auxiliary-boiler stop valve, diameter, inches	3½
Main-engine stop valve, inches	8

Forced Draft.—The closed fire-room system is used. In each fire room there are two single-inlet blowers. Each blower is driven by a simple, vertical, double-cylinder engine, enclosed in a dust-tight case. Both blowers and engines were made by the Union Iron Works.

Cylinders (2), diameter, inches	4
stroke, inches	4
Blower, diameter, feet and inches	4-9
number of vanes	6
width at rim, inches	9
center, inches	14
area of inlet (1), inches	36
at rim of blower, feet and inches	11-2

Main Feed Pumps.—There are four main feed pumps, one in each engine room and one in each fire room. The pumps are of the vertical, single-cylinder, double-acting Dow type, 10 inches by 6 inches by 12-inch stroke, each with a capacity of 147 gallons per minute. The main feed pumps draw from the feed tanks, the reserve feed-water tanks and the main air-pump channel ways. The main feed pumps in engine rooms deliver into the main feed system, either direct or through the feed-water heaters in their respective compartments, and into the feed-water tanks. But the main feed pump in one engine compartment does not discharge into the feed-water heater in the adjoining compartment. Each main feed pump in the fire rooms dis-

charges into the boilers in its compartment and into the main feed system.

Auxiliary Feed Pumps.—There are two auxiliary feed pumps, one in each fire room, and all of the same size, type and capacity as the main feed pumps. Each pump draws from the feed tanks, reserve feed tanks, from the boilers in its own compartment, the bilge and sea, and delivers into the boilers in its own compartment, fire main, spray pipes for putting out fires in boilers, and ash ejectors.

Fire and Bilge Pump.—In each engine room there is one vertical, single-cylinder, double-acting Dow pump, of 260 gallons capacity, with a 6 inch steam cylinder, 8-inch water cylinder, by 12-inch stroke, which draws from the sea and the bilge through the auxiliary drain pipe, and discharges into the fire main, overboard and into the pipes for putting out fires in the boiler furnaces.

Water-service Pump.—The distiller circulating pump in the after engine room is used for this purpose.

Feed Tanks.—In the forward engine room there is a feed tank of about 278 gallons capacity, and in the after engine room a similar tank of about 359 gallons capacity. A part of the upper portion of each tank is fitted as a filter into which the water from the air pump discharges, and after passing through the filtering material flows over a weir into the body of the tank. Each tank has a hinged cover for renewing the filtering material, a bolted cover in the body of the tank, and a glass water gauge with shut-off and drain cock, and has the following pipe connections:

Discharge pipes from the main and auxiliary air pumps and feed pumps; an overflow pipe to the bilge with a spring-loaded safety valve, break and funnel, so arranged that the overflowing water can be seen; a suction pipe to the feed pumps with an external shut-off valve and an internal balanced valve, so constructed as to prevent the admission of air to the feed pipes, and operated, automatically, by a copper float in tank and by a handle on the outside, a vapor pipe, and drain pipes from the traps.

Reserve Feed-water Tanks.—The reserve feed-water tanks are five in number and have a total capacity of 2,476 gallons. Three of them, holding 1,472 gallons, are located between frames Nos.

28 and 35, and two, containing 1,004 gallons, are located between frames Nos. 106 and 110. A common system of suction pipes connects them with all the feed pumps.

Steam Traps.—The separators, main and auxiliary steam pipes, the radiators, and all places where condensed steam can accumulate are fitted with drain pipes and valves and with automatic traps discharging into the feed tanks.

Steam Ejectors.—There is one steam ejector of 2,000 gallons capacity per hour in each engine and fire room for freeing the bilges of water and oil.

Ash Hoists.—In each fire room there is one 4-inch Horace See ash ejector, and at each fire-room hatch a whip for hoisting out clinkers, etc.

Distilling Apparatus.—In the after engine room there are two Union Iron Works bent-tube evaporators with a combined maximum capacity of 3,000 gallons of water per 24 hours, and one double-coil distiller with a capacity of 200 gallons of potable water, at 90 degrees Fahrenheit, in 24 hours. The evaporators take steam from the auxiliary steam line. There is one vertical, single-acting, distiller circulating pump, $3\frac{1}{4}$ inches by $4\frac{1}{2}$ inches by 6-inch stroke, and one horizontal, combined feed and brine pump, 3 inches by 2 and $1\frac{3}{4}$ inches by 3-inch stroke, both of the Dow type. The distiller has 16.75 square feet of cooling surface, and each evaporator has 61.5 square feet of heating surface.

Steering Engine.—On the floor of the forward conning tower there is a combined hand and steam-steering engine made by the Union Iron Works, of San Francisco, Cal. The engine is of the vertical, double-cylinder type, with cylinder 4 inches diameter and 4-inch stroke, and can be controlled from the bridge and conning tower. The wheel is in front of the engine, and its shaft passes directly below the cylinders, connecting by a secondary vertical shaft and gearing to the chain drum, which is driven by suitable spur and worm gearing on the engine shaft. On the floor of the after conning tower a hand-steering gear is placed for use in case of derangement to the steam gear. A wire rope, $\frac{3}{4}$-inch diameter, with $\frac{5}{8}$-inch chain connections to the steam and hand-steering gear, connects with the quadrant on rudder. The

tops of all steering wheels move in the direction of the course desired.

Steam Windlass and Winch.—On the forward platform there is a steam windlass built by the Hyde Windlass Company. The engine is of the horizontal, double-cylinder, reversible type, with cylinder 4½ inches in diameter by 4½-inch stroke, and transmits motion to the drums through a worm and gear. The drums, two in number, stand fore and aft and have a total capacity of 75 fathoms of 2¾-inch wire rope. A winch on the forecastle deck is operated by a vertical shaft driven by the windlass engine.

TORPEDO AIR COMPRESSOR.

There is one air compressor (Kasdowsky system) for the torpedo service, located in the after engine room. The compressor has one steam cylinder 9.252 inches in diameter; the stroke is 6.299 inches; the capacity 11,649 cubic feet per hour when making 260 to 275 revolutions per minute with 37.5 to 41.25 pounds of steam, the air pressure being 1,500 pounds per square inch.

Telegraph and Revolution Indicators.—In each engine room there is a mechanical telegraph, of the Stone type, connected to transmitters on the bridge and in the conning towers; a mechanical revolution indicator for showing the relative speed of the engines, and a mechanical telegraph for use between each engine room and its adjoining fire room. For the purpose of communication between engine rooms, a 12-inch port is placed in the bulkhead dividing the engine compartments. In conjunction with the transmitters on the bridge and in the conning towers, mechanical tell-tales showing the direction of the revolution of the main engines are fitted.

Voice Pipes.—Voice pipes, together with their wiring, annunciators, bells, buttons, etc., are fitted between the following points:

From forward bridge to forward conning tower, with a flexible connection in conning tower to forward engine room.

From forward conning tower to forward engine room.

From after conning tower to after engine room.

From forward engine room to forward fire room.

From after engine room to after fire room.

Electric Plant.—The installation consists in general of one 5-kilowatt generating set, 100 incandescent lights, one searchlight, one main switchboard and the necessary wiring, conduits, fixtures and accessories.

The generating set was made by the Union Iron Works, and consists of one 5-kilowatt dynamo of the multipolar type, with a capacity of 62.5 ampères at 80 volts, compound wound, four poles. The dynamo engine is of the single-cylinder, vertical type, diameter of cylinder, 5 inches by 4-inch stroke, and was designed to operate with 80 pounds of steam under a full load at 700 revolutions per minute. A cast-iron bed plate is common to both engine and dynamo.

The incandescent lights are of 5, 16 and 32 candlepower, designed for a potential of 80 volts. Suitable leads, run in iron-armored conduits, are provided for connecting the dynamo to the switchboard.

The switchboard is a single slate panel, and is supplied with one main-dynamo switch, four section switches for the lighting and battle circuits, and a switch and circuit breaker for the searchlight, besides the necessary dynamo and section fuses. There are two voltmeters and two ammeters of the round Weston switchboard pattern; one voltmeter and one ammeter being used exclusively for the searchlight circuit. The switchboard is also equipped with the necessary rheostats for dynamo and searchlight, and with a lamp ground detector and pilot lamps. The vessel is wired on the two-wire system.

There is one 18-inch hand-controlled searchlight, made by the Rushmore Dynamo Works, of Jersey City, New Jersey, mounted on a platform above the forward conning tower and connected in circuit with a rheostat installed beneath the main switchboard.

An electric torpedo-firing device is also installed, with a keyboard and firing contact maker in each conning tower. Using electric primers, a torpedo may be fired from either tube by completing the firing-battery circuit at either of the keyboards.

MACHINERY WEIGHTS IN POUNDS—(*PERRY*).

	Dry.	Wet.
Engine-room and stern weights, pounds	195,807	205,573
Forward fire-room weights, pounds	104,974	112,211
After fire-room weights, pounds	117,384	124,617
Tools, instruments and miscellaneous weights, pounds	...	7,121
Total weight		449,522

DETAILED WEIGHTS FOR TWO ENGINES.

Cylinder and fittings, pounds	Group I	45,370
Shafting, pounds	Group II	34,429
Reciprocating parts, pounds	Group III	28,059
Framing, bedplates and bearings, pounds	Group IV	9,211
Valves and valve gear, pounds	Group V	3,999
Condensers, pounds	Group VI	17,314
Air and circulating pumps, pounds	Group VII	6,372
Propellers (2), (A), pounds	Group VIII	3,296
Boilers (4), pounds	Group IX	131,667
Boiler fittings, pounds	Group X	36,438
Smoke pipes and uptakes, pounds	Group XI	11,755

PIPING AND MISCELLANEOUS.

Steam and exhaust pipes and valves, pounds	Group XII	21,463
Suction and discharge pipes and valves, pounds	Group XIII	20,663
Lagging and clothing, pounds	Group XIV	7,335
Floor plates, gratings and ladders, pounds	Group XV	6,783
Auxiliaries, pounds	Group XVI	17,787
Fittings and gear, pounds	Group XVII	12,897
Water, pounds	Group XVIII	25,236

The average tensile strengths of the various materials used on these boats are as follows:

	Tensile.	Minimum elastic limit.
Forged steel:		
Engine, main parts, except crank shaft	95,000	65,000
Columns, stays, pistons	80,000	50,000
Handgear, etc.	80,000	45,000
Ordinary forgings	60,000	30,000
		Per cent. elongation in 8 inches.
Cast steel:		
Subject to shock	60,000	15
Not subject to shock	70,000	10
Composition, 88 Cu., 10 Zn., 2 Sn.	34,000	14
Brazing metal, 90 Cu., 2 Zn., 8 Sn.	28,000	20
	Tensile.	Minimum elastic limit.
Manganese-bronze	60,000	40,000
Copper pipe, hydraulic test	6,000	.....
Brass pipe, hydraulic test	7,000	.....
Tobin-bronze, rolled rods	60,000	30,000
Phosphor-bronze, rolled rods	40,000	.....

AVERAGE WEIGHTS OF THE RECIPROCATING PARTS OF THE ENGINES FOR THE "PAUL JONES," "PERRY" AND "PREBLE."

.....	.....	H.P.	I.P.	F.L.P.	A.L.P.
Piston, pounds...	*Jones*...	248⅞	248	329	325
	Perry..	246½	256	325½	326½
	Preble..	244½	245½	326	327½
Piston rod and crosshead, pounds.....	*Jones*...	339	339	339	339
	Perry..	339	339	339	339
	Preble..	339	339	339	339
Connecting rod, complete, pounds.....	*Jones*...	528½	528½	519½	519½
	Perry..	528¼	528¼	519¼	519¼
	Preble..	528¼	528¼	519¼	519¼

TRIALS.

First trial of *Perry* from February 25th to April 5th, 1901.

The official and contractors' trials of the *Paul Jones*, *Perry* and *Preble* were all made in San Francisco Bay. According to the contract each vessel was required to make two trials: a progressive-speed trial, for the purpose of standardizing the propellers up to 29 knots, and a continuous two-hour trial at the average number of revolutions, as determined by the previous trial, necessary for a speed of 29 knots per hour.

The *Perry* was the first of these vessels to be tried, and the first Trial Board convened at the Union Iron Works on February 19, 1901.

On February 25th, the vessel having previously had a dock trial, left the Union Iron Works at 11 A. M., with the Trial Board, for the purpose of making her official progressive-speed trial. The wind and sea being favorable, several double runs at the lower speeds were made, but, owing to unsatisfactory working of the automatic stop valves on the boilers, the trial was discontinued.

Subsequent attempts were made on March 4th, 7th, 12th, 14th, 19th, 27th, and on April 2d and 5th to complete the progressive speed trial of this vessel, all of which, excepting that of April 2d (discontinued on account of the weather) were discontinued on account of the heating of some of the engine bearings or the unsatisfactory action of the automatic stop valves on the boilers.

After the second official trial, on March 4th, the automatic stop valves were removed, and all subsequent attempts made by this Board were made without these valves being in place. Just previous to the third attempt to complete the progressive-speed trial, on March 12th, the vessel was docked and about 34 feet of the forward ends of the bilge keel removed in order to decrease the vessel's resistance.

Owing to the difficulty in maintaining the boiler pressure, the contractors decided, immediately after the sixth trial, on March 19th, to fit a fire-brick arch at the apex of the tubes in each of the boiler furnaces in order to check the too-ready escape of the gases. This very materially improved the steaming capacity of the boilers, as was evidenced by the subsequent trials.

At anything over 26 knots the heating of the after crank-shaft bearings of the port and starboard engines, the H.P. and I.P. crank pins, the starboard H.P. crosshead pin and both thrust bearings gave considerable trouble.

The highest average speed obtained during this series of trials was 28.2 knots with 338.5 revolutions, and the result of these trials forced the conclusion that with an excess of about 55.6 tons in the displacement, due to overweight of 2.38 tons in the machinery and 53.22 tons in the hull, taken in conjunction with the increased resistance offered by the hooked shape of the stern, it was not possible to comply with the terms of the contract in the matter of speed.

Acting on this conclusion, the contractors proposed to the Department a plan for altering the sterns of these vessels, which was taken under consideration, pending the settlement of which, the Trial Board adjourned.

The Bureau of Steam Engineering, not being satisfied with the propellers fitted to the *Perry*, directed that new propellers, having a helicoidal area of about 20 square feet each, be substituted for those used during the trials.

These propellers (marked *B* in Plate A) were made, but a strike at the works, occurring shortly after, prevented any further trial of this vessel until the following February, when the vessel (the stern having been altered as shown in Plate B) was again tried with the propellers (A) used by her on her first trials.

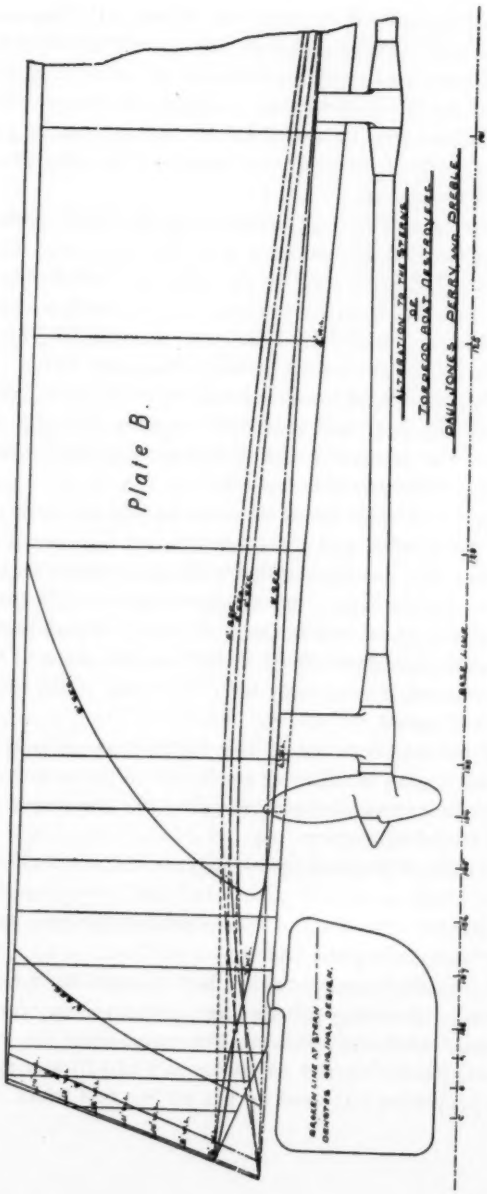


Plate B.
ALTERATION TO THE STEAM
OF
TORPEDO BOAT DESTROYERS
PAUL JONES, PERRY AND PREBLE.
BROKEN LINE AT STEAM
SHOWS ORIGINAL DESIGN.

TABLE I.—STEAM LOG OF TORPEDO-BOAT DESTROYER NO. 11, *PERRY*.—RUNS OVER MEASURED COURSE, SAN FRANCISCO BAY. FOR STANDARDIZATION OF PROPELLERS.

No. of run.	Time.	Speed.	Mean speed (2 runs).	Revolutions of main engines.				Steam pressures.						Throttle in holes.		Vacuum.		Temperature, in degrees.								Air pressure.	Inches of water.
								Gauge.		Absolute.								Injection.		Discharge.		Feed.		Engine room.			
				Port.	Starboard.	Average P. and S.	Mean av. P. and S.	At engines.		1st receiver.		2d receiver.															
	M. S.	*Knots.*	*Knots.*	*Per run.*		*Per min.*	*2 runs.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*
1	2 32	23.914	24.171	732	733	289.54	287.2	270	265	82	70	21	20	$\frac{1}{16}$	1	27	26	61	65	90	89	88	90	93	97	$2\frac{1}{4}$	2
2	2 28.8	24.429		698	715	284.87		252	253	65	68	19	20	1	1	26	26	67	65	88	90	105	98	90	95	$2\frac{3}{8}$	$1\frac{1}{4}$
3	2 41.2	22.55	25.044	711	725	267.24	291.62	217	214	53	57	17	16	1	1	27	26	67	67	87	90	110	100	90	98	$2\frac{3}{8}$	$\frac{1}{4}$
4	2 12	27.508		684	706	316		269	266	76	84	23	25	$1\frac{1}{16}$	$1\frac{3}{16}$	26	26	66	66	85	95	95	90	81	98	3	1
5	3 34	16.987	19.72	774	744	212.8	212.64	283	278	33	28	7	...	$\frac{1}{16}$	...	27	26	60	70	99	93	93	97	97	102	$\frac{3}{8}$	$\frac{1}{4}$
6	2 41.8	22.466		575	571	212.48		281	282	36	30	8	1	$\frac{1}{16}$	$\frac{1}{16}$	27	27	60	70	103	95	98	95	109	103	$\frac{1}{4}$	$\frac{1}{4}$
7	2 57.6	20.467	23.31	782	792	265.87	269.12	261	263	60	62	12	15	$\frac{1}{16}$	$\frac{1}{16}$	26	27	62	66	103	94	90	89	108	104	$2\frac{1}{4}$	$\frac{1}{8}$
8	2 19	26.151		626	636	272.37		272	266	59	60	15	17	$\frac{1}{16}$	$\frac{1}{16}$	26	27	63	70	106	95	95	92	101	104	2	$1\frac{1}{4}$
9	2 30.4	24.169	26.69	788	794	315.55	305.5	266	265	75	85	24	25	$1\frac{1}{16}$	$1\frac{1}{16}$	26	26	62	65	99	96	96	102	101	106	$3\frac{1}{2}$	$2\frac{1}{2}$
10	2 04.4	29.221		646	646	295.5		244	248	82	85	25	25	$1\frac{1}{4}$	$1\frac{1}{4}$	26	26	63	63	94	99	97	100	82	103	3	$2\frac{1}{2}$
11	2 32.4	23.852	26.11	799	805	315.74	308.1	227	232	89	85	26	26	$3\frac{3}{8}$	$3\frac{1}{2}$	25	26	61	64	95	97	117	104	86	92	$3\frac{3}{8}$	3
12	2 08.6	28.266		643	645	300.46		205	205	78	85	23	24	4	$3\frac{1}{2}$	26	26	62	63	95	94	115	103	93	92	$2\frac{3}{8}$	$3\frac{1}{4}$
13	2 04.8	29.127	27.677	679	682	327.1	333.2	267	268	92	90	28	30	$2\frac{1}{2}$	$2\frac{1}{2}$	26	26.5	56	59	92	87	97	100	92	101	$2\frac{7}{8}$	$2\frac{1}{4}$
14	2 18.6	26.277	28.2	777	790	339.1	338.5	277	278	100	105	30	33	$3\frac{1}{2}$	$3\frac{5}{8}$	26	26	56	57	94	90	105	120	92	102	$3\frac{1}{2}$	$2\frac{3}{4}$
15	2 00.4	30.192		676	682	338		275	274	97	105	31	34	$3\frac{1}{2}$	$3\frac{5}{8}$	26	26	55	56	92	88	105	120	96	100	$4\frac{1}{2}$	4

Runs 1 to 4, inclusive, were made March 12, 1901; runs 5 to 12, inclusive, were made March 14, 1901; runs 13 to 15, inclusive, were made April 5, 1901. Steam pressure at boiler was from 2 to 3 pounds above pressure in engine room, natural fall.

The several double runs made during these attempts were made as nearly as practicable at the rates of speed prescribed by the precept and instructions for the trial. At a given signal by the observer, who marked with a stop watch the time of passing the range marks placed at the ends of the measured mile course, the four counters, (during the latter trials these were all on deck,) were thrown in and out of gear at the moment of entering on and leaving the course.

Indicator cards were taken from both engines, and readings of the engine-room gauges were taken and recorded during each run.

The data observed from the deck and engine rooms for each run, beginning with the third attempt, on March 12, and ending with the final effort, on April 5, are recorded in Table I.

DATA OF STANDARDIZATION TRIAL OF THE "PERRY," FEBRUARY 23 TO APRIL 5, 1901.

Draught at beginning of trial, forward, feet and inches	6– $\frac{1}{2}$
aft, feet and inches	8–3$\frac{1}{2}$
mean, feet and inches	7–2$\frac{1}{4}$
ending of trial, forward, feet and inches	5–10
aft, feet and inches	8–3$\frac{1}{2}$
mean, feet and inches	7– $\frac{17}{24}$
Displacement at beginning, tons	475.6
ending, tons	462.73

The above data was read from the mean of salt and fresh-water curves and draughts taken at the Union Iron Works before leaving and after returning, respectively.

SECOND TRIAL OF "PERRY," APRIL 26, TO APRIL 30, 1902.

The work of changing the sterns of the *Paul Jones*, *Perry* and *Preble* having been carried out in accordance with the Department's plan, as shown on Plate B, the *Perry* was again prepared for trial. The second Trial Board convened at the Union Iron Works on April 23d, at 10 A. M., and accompanied the *Perry* on a preliminary run over the trial course on the afternoon of that day. No attempt was made at speed, and, with the exception of the steering engine, all the machinery worked well.

On April 26th, at 8·30 A. M., the *Perry* left the Union Iron

TABLE II.—STEAM LOG OF TORPEDO-BOAT DESTROYER No. 11, *PERRY*.—RUN OVER MEASURED COURSE, SAN FRANCISCO BAY FOR STANDARDIZATION OF PROPELLERS.

No. of run.	Time.	Speed.	Mean speed, 2 runs.	Revolutions of main engines.				Steam pressures.						Throttle in holes.		Vacuum.		Temperature, in degrees.								Air pressure, inches of water.	
								Gauge		Absolute.								Injection.		Discharge.		Feed.		Engine room.			
				Port.	Starboard.	Average P. and S.	Mean av. P. and S.	At engines		1st receiver.		2d receiver.															
	M. *S.*	*Knots.*	*Knots.*	*Per run*	*Per run*	*Per min*	*2 runs.*	*P.*	*S.*	*P.*	*S*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*
1	3 30½	17.269	18.817	732½	739	209.72	208.89	285	300	45	45	7½	9	Crack	Crack	27	26	63	62	99	87	80	80	90	96	2	...
2	2 58½	20.364		621	617	208.07		288	285	60	75	12½	10	Crack.	1¼	27	26	63	63	97	87	90	78	90	96	...	...
3	2 26½	24.813	26.334	785	817	328.26	332.82	225	240	100	110	32½	30	2¼	5¾	25	23	60	63	116	94	105	107	90	94	2	4
4	2 10½	27.855		718	750	337.47		260	260	105	120	34½	33	3	Full.	26	22	59	66	100	95	118	125	90	90	3½	4½
5	2 27½	24.644	25.235	769	775	314.03	312.03	200	200	100	105	32½	37½	8½	Full.	26	23	60	67	95	94	120	128	90	90	4	4
6	2 20¾	25.825		728	726.5	310.02		295	295	80	72	27	27	¼ cr.	¼ cr.	28	27	60	66	92	96	105	120	85	86	2	½
7	2 42	22.438	22.508	742	728	272.22	265.06	270	270	100	100	34	37½	3	Full.	27	27	60	64	95	95	105	107	90	90	4	4½
8	2 41	22.578		688	696	257.89		220	210	95	105	32	38	3	Full.	25	24	60	67	95	96	105	122	90	92	4	4½
9	2 24	25.243	25.986	745½	777	317.19	320.34	240	240	110	110	40	38	Full.	Full.	25	23	59	69	95	100	115	125	90	90	4	4½
10	2 16	26.728		726½	740	323.49		220	298	110	110	34	39	Full.	Full.	25	22	60	67	95	98	115	120	90	90	4	4½
11	2 23	25.420	26.124	761	757	318.46	325.95	240	260	110	110	34½	38	Full.	Full.	25	23	60	65	95	98	125	125	90	88	4½	4
12	2 15½	26.827		748	758	333.43		250	250	110	110	37	37	Full.	Full.	25	23	60	65	95	98	115	125	90	90	4½	4½
13	2 41	22.578	26.006	805	836	305.775	324.51	260	260	105	100	37½	38½	Crack	$\frac{1}{10}$	25	25	65	65	105	81	120	100	83	85	4½	4½
14	2 03½	29.434		708	705	343.24		265	260	105	110	36½	40½	Open.	7	26	25	59	65	155	85	155	105	90	85	4½	4½
15	2 26½	24.812	27.396	860.5	869	354.16	355.72	260	260	115	125	44½	45½	Open.	9	25	24	60	65	109	90	125	120	90	85	4½	4½
16	2 01½	29.979		722.5	721.5	357.28		260	255	115	125	42½	45½	Open.	Full.	24	24	60	65	90	90	120	120	90	82	4½	4½
17	2 24½	25.156	27.445	875	875.5	363.43	355.15	255	265	120	125	42½	45½	Open.	Full.	24	24	60	65	90	93	120	125	90	85	4½	5
18	2 02½	29.733		704.5	709	346.865		255	240	120	120	42½	43½	Open.	Full.	24	25	60	65	90	94	120	125	90	86	4½	4½
19	2 24½	25.112	27.577	842.5	839	348.495	345.70	255	260	120	120	42½	43½	Open.	Full.	25	25	60	65	90	92	120	130	90	85	4½	4½
20	2 01	30.041		699	684	342.893		250	255	120	120	41½	43½	Open.	Full.	25	24	60	65	90	95	120	130	90	90	4½	4½
21	2 20	25.964	28.319	870	869	372.644	369.93	260	260	120	130	42½	47½	Full.	Full.	24	23	60	65	90	95	120	130	90	87	4½	5
22	1 58½	30.675		722.5	728	367.216		265	265	120	130	42½	47½	Open.	Full.	24	23	60	67	95	99	120	130	90	90	4	4½

Runs 1 to 12, inclusive, were made on April 26, 1902; runs 13 to 22, inclusive, were made on April 30, 1902. Steam pressure at boiler was from 2 to 3 pounds above pressure in engine room.

Works with the Trial Board to conduct her progressive-speed trial in accordance with the precept and modified conditions as to speed for this trial, the Department having, on February 26th, 1902, directed that the progressive-speed trials of these vessels be carried to the highest attainable speed, and fixing 28 knots per hour as the lowest satisfactory rate, also that a continuous run of one hour's duration at an average number of revolutions required for a speed of 26 knots be substituted for the two-hours' run at an average speed of 29 knots as originally called for in the contract.

During this trial six double runs were made over the Bluff Point course, the highest average speed being 26.32 knots at 333 revolutions per minute. Owing to the heating of the starboard H.P. crosshead pin and the port H.P. crank pin, the trial was discontinued, the vessel returning to the Union Iron Works about 11 A. M.

Previous to this trial, the contractors removed the water circulation from the thrust bearings and substituted a forced oil circulation, in conjunction with which a "cooler" was fitted, the oil passing alternately through the thrusts and coolers. This device proved very efficient in keeping the thrusts cool. The necessary changes to the boiler automatic stop valves having been made, they were placed in position and operated satisfactorily during the trial.

On April 30th, at 10 A. M., the *Perry* again left the Union Iron Works to complete the progressive-speed trial. Five double runs were made, the highest average speed being 28.32 knots with 369.93 revolutions, thus completing the progressive-speed trial of this vessel. Owing to the heating of the starboard H.P. crosshead pin and the after L.P. main bearing, it was not deemed expedient to attempt the one-hour's continuous trial, and the vessel returned to the works about 1 P. M.

The observed data taken during the standardization trials is given in Table II.

The maximum card, No. 10, taken on run No. 21, was taken from the starboard engine during this trial, and gives an I.H.P. of 4,576.85 at 372.6 revolutions. Assuming the horsepower of

the port engine to have been about the same, the combined horsepower for both engines would be over 9,100. The corresponding card for the port engine was not taken.

TABLE III.—STEAM LOG U. S. S. *PERRY*, OFFICIAL TRIAL OF ONE HOUR, MAY 7, 1902, IN SAN FRANCISCO BAY.

Time.	Revolutions per minute.			Steam pressure per gauge.			Vacuum.	Throttle in holes.	Temperatures.				Air pressure, inches of water.
	Starboard.	Port.	Average.	At engine.	1st receiver.	2d receiver.			Injection.	Discharge.	Feed.	Engine room.	
10·24	...	...	...	267	85	19.	24	2	65	95	105	100	4
					100	22.5				93		95	
10·29	346.6	347.4	347.	...	...	...	...	...	...	...	...	...	...
10·34	349.6	349.	349 3	...	...	...	...	...	...	...	...	...	...
10·39	352.2	350.4	351.3	260	100	19.5	24	4	65	90	120	90	5
				265	110	24.5			60	102			
10·44	344.4	346.	345.2	...	...	...	...	...	...	...	...	...	...
10·49	346.4	344.6	345.5	...	...	...	...	...	...	...	...	...	...
10·54	349.8	347.8	348.8	260	90	19.5	26	½ open	60	90	120	90	5
					110	24.5	23			95			
10·59	354.4	353.8	354.1	...	...	...	...	...	...	...	...	...	...
11·04	344.	339.6	341.8	...	...	...	...	...	...	...	...	...	...
11·09	346.2	344.8	345.5	260	90	19.5	25	½ open	60	90	120	90	5
					110	24.	23			99	125	95	
11·14	343.8	341.	342.4	...	...	...	...	...	...	...	...	...	...
11·19	341.8	336.8	339.3	...	...	...	...	...	...	...	...	...	...
11·24	354.2	348.4	351.3	255	90	19.5	25	½ open	60	90	120	90	5
					110	24.	23			95	125	95	

Mean average revolutions for one hour, 346.708.
Mean speed, 27.2 knots per hour.
I.H.P., 8,000. In columns having two rows of figures, the upper row refers to the port engine and the lower to starboard engine.
Coal per hour, 22,029 pounds.
Coal used was Cardiff coal.
Coal per I.H.P. per hour, 2.754 pounds.

ONE-HOUR'S TRIAL OF "PERRY," MAY 3 TO MAY 7, 1902.

On May 3 the *Perry* left the Union Iron Works at 10 A. M. to make her official one-hour's continuous trial at an average speed of not less than 26 knots, *the course being around Angel Island.* The wind and sea were favorable. Owing to the starboard condenser leaking, the trial was not commenced, and, after steaming about the bay for about one hour and a half, the vessel returned to the works, about 11·30 A. M.

On May 7, about 9·50 A. M., the *Perry* again left the Union Iron Works to make her one-hour's continuous trial.

This trial commenced at 10·25 A. M. and lasted until 11·25 A. M., the average revolutions per minute being 347.5, giving a speed of 27.1 knots per hour. The conditions of wind and sea were favorable.

The vessel was then given her helm and turning evolutions, all of which being satisfactory, she returned to the Union Iron Works about 12·30 P. M. During this trial the machinery performed satisfactorily.

The four counter readings, all of which were taken on deck, were recorded every five minutes, and the engine-room gauges read and recorded every ten minutes.

The observed data is given in the preceding table: (III.)

The coal used during the trial was Cardiff hand-picked, supplied to the fire room in 100-pound bags, weighed by the contractors and checked by the naval constructor.

The quantity of coal used per hour was 22,029 pounds.

DATA OF STANDARDIZATION TRIALS OF "PERRY," APRIL 26, 1902.

Draught at beginning of trial, forward, feet and inches	6– ½
aft, feet and inches, starboard	8–3½
port	8–4
mean, feet and inches	7–2.125
ending of trial, forward, feet and inches, aft, feet and inches, mean, feet and inches	Not taken, owing to rough water.
Displacement at beginning, tons	475.6

APRIL 30, 1902.

Draught at beginning of trial, forward, feet and inches	6–1½
aft, feet and inches, starboard	8–5
port	8–5
mean, feet and inches	7–4½
ending of trial, forward, feet and inches, aft, feet and inches, mean, feet and inches	Not taken, owing to rough water.
Displacement at beginning, tons	475.6

Above was read from mean of salt and fresh-water curves and draughts taken at Union Iron Works before starting. Owing to the roughness of the water, the draught at end of trial was not taken.

DATA FOR ONE-HOUR TRIAL RUN OF "PERRY," MAY 7, 1902.

Hull weights to date, tons	203.114
Steam-engineering weights, not including water in pipes, condensers and boilers, tons	189.850
Ordnance weights, including air-compressor plant and piping, tons	15
Articles comprising equipment within the meaning of the contract, tons	12
Water in condensers, pipes and boilers, tons	10.82
Reserve feed water, tons	9.225
Total, tons	440.009
Put on board for trial:	
Coal, tons	25
Men, tons	4.262
Provisions, temporary outfit, oil, etc., tons	3.571
Total, tons	32.833
Grand total, tons	472.842
Draught at beginning of trial, forward, feet and inches	6-1
aft, feet and inches, starboard	8-4½
port	8-4
mean, feet and inches	7-2⅝
Displacement from curves, tons	480.21
Draught at end of trial, forward, feet and inches	5-10
aft, feet and inches, starboard	8-4
port	8-3½
mean, feet and inches	7-1.3
Displacement from curves, tons	462.73
mean for trial, tons	471.47

The official report of the speed for one hour was 27.1 knots, at 347.5 revolutions per minute.

Immediately after the trial the vessel was given her evolution trials, the results of which are given below:

Time to put helm from amidship to hard aport, seconds	6
astarboard, seconds	8
hard astarboard to hard aport, seconds	12
aport to hard astarboard, seconds	12½
Turning:	
Angle of heel, degrees, turning to starboard	14
port	13
Time to turn, 180 degrees, to starboard, seconds	55
port, seconds	55
Tactical diameter, estimated in yards, to starboard	300
port	300

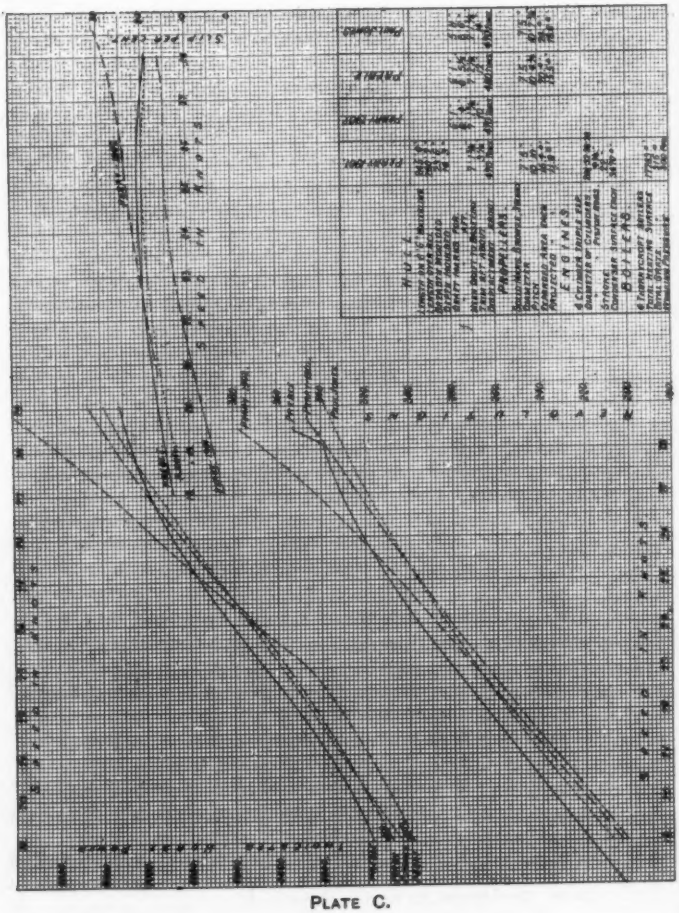


PLATE C.

Change of Trim.—The change of trim while at full speed of 27 1 knots was 5 feet 4.7 inches.

The curves for the horsepower, speed and slip for this vessel are shown, in conjunction with those for the *Preble* and *Paul Jones*, on Plate C.

The work, remaining unfinished at the time of the trial, being completed, the *Perry* was delivered at Mare Island Navy Yard on May 31, 1902.

PREBLE.

The *Preble* was given a dock trial on May 19th, 1902, and the contractors' preliminary trial on May 20th. The vessel was then put in dry dock, cleaned and painted, and the propellers with which she was originally fitted were removed and replaced by the propellers (marked *B* in plate A), originally intended to meet the Bureau's desires in the matter of an increase in the helicoidal area for the propellers of the *Perry*, as considered at the time of her first trials from February 23d to April 5th, 1901.

The *Preble* left the Union Iron Works about 9·30 A. M., on May 24th, to make her official progressive-speed trial over the Bluff Point course, the wind and sea being favorable. After making six standardization runs, the trial was discontinued owing to the heating of the starboard I.P. crank pin. The highest average for this trial was 27.491 knots at 329.2 revolutions per minute.

On May 27th, the *Preble* again left the Union Iron Works about 9·40 A. M., to complete the standardization trials, and also to make the one-hour's run, if circumstances permitted. On this trial the vessel made seven standardization runs, thus completing the standardization trial. The highest average made on this date was 28.08 knots, with 336.815 revolutions per minute.

The maximum card, No. 9, taken during this standardization run, gives for the starboard engine an I.H.P. of 3,623 at 338.06 revolutions per minute. The corresponding cards from the port engine were not taken.

Immediately after the completion of the standardization trial, the one-hour's continuous trial was commenced and finished satisfactorily. The mean speed for the hour was 27.85 knots

with 335.199 revolutions per minute. No cards were taken during the one-hour's trial.

DATA FOR STANDARDIZATION TRIAL OF "PREBLE."

Draught at beginning of trial, forward, feet	6
aft, feet and inches	8–4½
mean, feet and inches	7–2¼
Displacement, tons	474.7
Draught at end of trial, forward, feet and inches	5–11
aft, feet and inches	8–4½
mean, feet and inches	7–1⅝
Displacement, tons	469.1

Above was read from mean of salt and fresh-water curves and draughts at Union Iron Works before starting and after returning, respectively.

The following Tables IV and V give the data obtained during the standardization and one-hour's trials for the *Preble*. The total weight of the machinery was 201.23 tons, being 3.23 tons in excess of the penalty weight. The displacement at trials was 474.7 tons, being about 54.7 tons in excess of the specification displacement.

The machinery and boilers operated satisfactorily, and the vibration at the stern was considerably less than it was in the case of the *Perry*.

The vessel was completed and delivered at Mare Island Navy Yard on June 21st, 1902.

DATA FOR ONE HOUR'S TRIAL RUN, "PREBLE."

Hull weights to date, tons	201.631
Steam-engineering weights, not including water in pipes, condensers and boilers, tons	190.410
Ordnance weights, including air-compressor plant and piping, tons,	15
Articles comprising equipment within meaning of contract, tons	12
Water in condensers, pipes and boilers, tons	10.82
Reserve feed water, tons	9.225
Total, tons	439.086
Put on board for trial :	
Coal, tons	25
Men, tons	4.262
Provisions, temporary outfit, oil, etc., tons	3.374
Total, in tons	32.636
Grand total, tons	471.722

She was then given her helm and turning evolutions with the following results:

Time to put helm from amidship to hard aport, seconds	5½
astarboard, seconds	6
hard astarboard to hard aport, seconds	12
aport to hard astarboard, seconds	12
Turning:	
Angle of heel, degrees, turning to starboard	25 to 35
port	25 to 35
Time to turn, 180 degrees, to starboard, minutes and seconds	1–40
port, minutes and seconds	1–50
Tactical diameter, estimated in yards, to starboard	300
port	300

Change of Trim.—The change of trim at full speed of 27.831 knots was 5 feet 8½ inches.

PAUL JONES.

The *Paul Jones* was launched at 7·10 P. M., June 14, 1902. She was given a dock trial on June 22, a contractors' preliminary trial on June 28, and left the Union Iron Works at 9·30 A. M. on July 2 for her standardization trial over the Bluff Point course. During this trial four double runs were made, the highest being 19.557 knots, with 213.309 revolutions.

Owing to accidental leakage of sea water to the suction side of the auxiliary feed pump in the after boiler room, the boilers in this compartment became charged with salt water, and the trial had to be discontinued on account of the priming of these boilers, and the vessel returned to the works about 12·30 P. M. During this trial the force of the wind was 4 and the sea smooth.

On July 8 the *Paul Jones* again left the Union Iron Works, about 9·45 A. M., to complete the standardization trial and make the one-hour's continuous run. During this trial six double runs were made, the highest average speed being 28.91 knots, with 336.489 revolutions.

The maximum card, No. 16, taken during standardization run No. 16, gives an indicated H.P. of 7,819 for the two engines.

No cards were taken during the one-hour's trial. During this trial the force of the wind was about 4 and the sea smooth.

TABLE IV.—STEAM LOG OF TORPEDO-BOAT DESTROYER No. 11, *PREBLE*.—RUNS OVER MEASURED COURSE, SAN FRANCISCO BAY, FOR STANDARDIZATION OF PROPELLERS.

No. of run.	Time.	Speed.	Mean speed (2 runs).	Revolutions of main engines.				Steam pressures.						Vacuum.		Throttle in holes.		Temperature, in degrees.								Air pressure.	
								Gauge		Absolute.								Injection.		Discharge.		Feed.		Engine room.			
				Starboard.	Port.	Average P. and S.	Mean av. P. and S.	At engines.		1st receiver.		2d receiver.															
	M. *S.*	*Knots.*	*Knots.*	*Per run*	*Per run*	*Per min.*	*2 runs.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*
1	2 54.8	20.795	20.157	692	689	237.016	238.86	280	280	40	40	15	15	20	20	½	Open.	60	60	90	90	125	125	92	90	3	3
2	2 59.6	20.239		725	716	240.704		300	295	45	45	15	15	20	27	½	½	60	60	90	90	...	...	92	90	4	4½
3	2 14	27.127	25.664	714	727	322.617	313.208	260	260	85	85	33	34	18	27	½	½	60	60	90	90	...	...	90	90	4	4
4	2 30.2	24.201		758	762.5	303.799		280	280	75	85	30	30	18	28	½	½	60	60	90	90	...	...	90	90	4	5
5	2 07	28.622	27.941	709.5	711	335.561	329.204	250	260	105	100	37	40	18	29	3	½	60	60	90	90	...	...	90	90	4½	4½
6	2 17.9	26.360		701	783	322.847		250	260	100	105	35	35	20	27	3	3	60	60	90	90	...	...	90	90	4	4
7	2 16	26.728	27.881	766	770 5	338.933	336.299	210	230	95	105	38	34	25	26½	5	½	60	60	88	90	125	125	92	90	4	5
8	2 05.2	29.034	28.080	692	700.5	333.666	236.815	200	230	95	105	36	35	26	27	5	½	61	60	90	90	125	125	90	90	4	4½
9	2 14	27.127		755	763.5	339.963		260	260	105	105	35	35	26	26	5½	½	62	60	90	90	125	125	90	90	4	4½
10	2 35.5	23.397	22.795	700	704.5	270.965	273.196	290	265	55	60	20	20	27	28	1	1	65	60	90	90	125	125	90	90	4½	5
11	2 43.8	22.192		751	753	275.426		300	290	55	60	20	21	27	26	1	1	65	60	90	91	125	125	90	90	4½	4½
12	2 58	20.421	18.959	661	688.5	227.445	215.564	280	280	35	35	15	15	27	27	1	1	60	60	90	90	125	125	90	90	½	4½
13	2 27.75	17.497		698	712.5	203.682		300	300	30	30	14	14	18	27	1	1	62	60	90	90	125	100	90	90	½	4½

Runs 1 to 6, inclusive, were made on May 24, 1902; runs 7 to 13, inclusive, were made on May 27, 1902. Steam pressure at boiler was from 2 to 3 pounds above pressure in engine room.

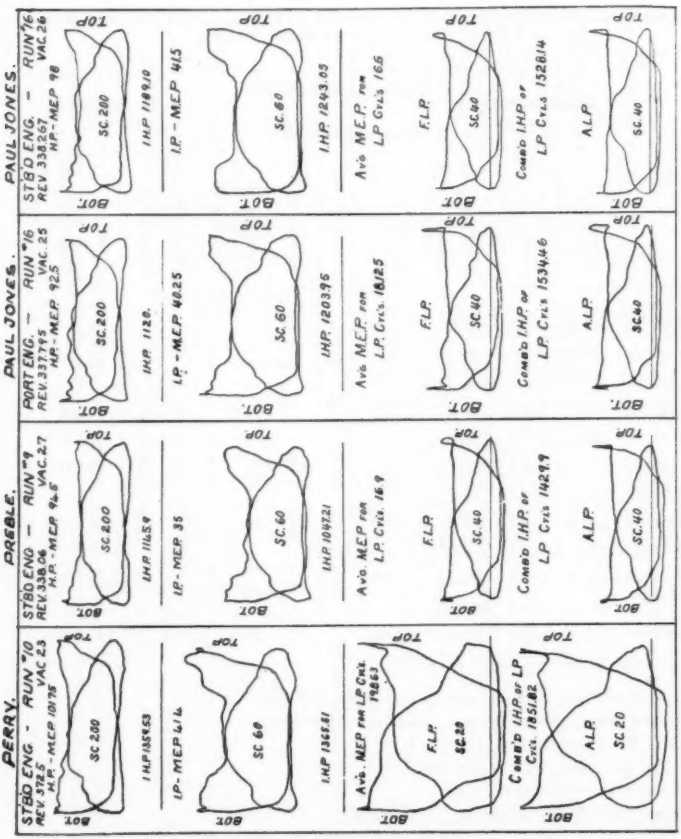
TABLE V.—STEAM LOG U. S. S. *PREBLE*, OFFICIAL TRIAL OF ONE HOUR, MAY 27, 1902, IN SAN FRANCISCO BAY.

Time.	Revolutions per minute.			Steam pressures.			Vacuum.	Throttle in holes.	Temperatures.				Air pressure.
				Gauge.	Absolute.								
	Starboard.	Port.	Average.	At engine.	1st receiver.	2d receiver.			Injection.	Discharge.	Feed.	Engine room.	
11·26·30	...	...	...	...	...	...	...	...	...	...	...	...	...
11·31·30	322.8	310.7	316.8	...	...	...	...	..	...	...	...	...	...
11·36·30	326.6	324.	325.3	255 250	85 80	35 30	27	4 2	60	90 85	95 90	90	4½
11·41·30	331.6	337.2	334.4	...	...	...	...	...	...	...	...	...	...
11·46·30	333.	341.8	337.4	255 260	105 90	35 31	27	4 3	60	90 84	90	90	4
11·51·30	334.4	336.6	335.5	...	...	...	...	...	...	...	...	...	...
11·56·30	337.2	342.8	340.	255 260	100 95	40 33	27 26	4 3	60	90 85	90	90	4
12·01·30	336.2	343.2	339.7	...	..	...	...	...	...	...	...	...	...
12·06·30	336.8	340.8	338.8	260	100 95	40 35	27	4 3	60	90 87	105	90	4
12·11·30	337.	340.4	338.7	...	...	...	...	...	...	...	...	...	...
12·16·30	339·2	340.8	340.	260	100 85	40 35	26 27	4 2	60	90	105	90	4
12·21·30	337.	340.8	338.9	...	...	...	...	...	...	...	...	...	...
12·26·30	337.2	337.2	337.2	260	100 85	40 35	26	4 3	60	90 92	105	90	4

Mean average revolutions for one hour, 335.199.
Mean speed (from curve), 27.55 knots per hour.
I.H.P. (from curve), 7,110.
Coal per hour, 23,400 pounds.
Coal used was Cardiff coal.
Coal per I.H.P. per hour, 3.29 pounds.
In columns having two rows of figures, the upper row refers to the port engine and the lower to starboard engine.

After the completion of the standardization trial the one-hour's trial was commenced, at 11·38 A. M., and ended at 12·38 P. M.

The official report of the speed for this trial was 27.4 knots, with 322.4 revolutions, thus giving the *Paul Jones* the highest average speed of these three vessels.



STANDARDIZATION TRIALS, *PERRY, PREBLE* AND *PAUL JONES*, 1902.
MAX. POWER INDICATOR CARDS TAKEN ON TRIALS.

DATA FOR STANDARDIZATION TRIAL OF "PAUL JONES."

Draught at beginning of trial, forward, feet and inches	5–11
aft, feet and inches	8–6
mean, feet and inches	7–2½
Displacement, tons	474.5
Draught at end of trial, forward, feet and inches	5–8¼
aft, feet and inches	8–4½
mean, feet and inches	7– ½
Displacement, tons	...

Above was read from mean of salt and fresh-water curves and draughts taken at Union Iron Works before starting and after returning, respectively.

The vessel was then given her helm and turning evolutions with the following results:

Time to put helm from amidship to hard aport, seconds..... 3½
astarboard, seconds..... 4½
hard astarboard to hard aport, seconds..... 10½
aport to hard astarboard, seconds..... 10½

Turning:
Angle of heel, degrees, turning to starboard..... .....
port..... .....
Time to turn, 180 degrees, to starboard, minutes and seconds..... 1–10
port, minutes and seconds..... 1–10
Tactical diameter, estimated in yards, to starboard..... 350
port..... 350

STEAM LOG OF TORPEDO-BOAT DESTROYER No. 10, *PAUL JONES*.—OFFICIAL TRIAL OF ONE HOUR, JULY 8, 1902, IN SAN FRANCISCO BAY.

Time.	Revolutions per minute.			Steam pressure.			Vacuum.	Throttle in holes.	Temperatures.				Air pressure.
				Gauge.	Absolute.								
	Starboard.	Port.	Average.	At engine.	1st receiver.	2d receiver.			Injection.	Discharge.	Feed.	Engine room.	
11'38	...	...	...	...	...	...	...	...	...	...	...	...	...
11'43	340.6	343.6	342.1	...	...	...	...	...	...	...	...	...	...
11'48	324.2	318.	321.1	...	...	...	...	...	...	...	...	...	...
11'53	320.4	321.6	321.	270	90	28	27	4	60	105	95	100	4½
11'58	320.	324.	322.										
12'03	319.	321.8	319.9	265	95	29	27	full	60	105	95	100	4½
12'08	318.	322.	320.										
12'13	320.6	322.4	321.5	...	...	...	...	...	...	...	...	...	...
12'18	316.	321.4	318.7	...	...	...	...	...	...	...	...	...	...
12'23	320.8	318.8	319.8	255	90	24	27	full	60	105	95	95	4½
12'28	315.6	320.2	317.9										
12'33	309.2	305.8	307.5	220	80	24	27	full	60	105	95	98	4
12'38	309.2	304.6	306.9										

Steam pressure at boilers from 2 to 3 pounds above pressure in engine room.
Mean average revolutions for one hour, 322.4.
Mean speed (from curve), 27.3.
I.H.P. (from curve), 6,925.
Coal used was Cardiff coal.
Coal per hour, 16,200 pounds.
Coal per I.H.P. per hour, 2.34.

STANDARDIZATION TRIALS, *PERRY, PREBLE* AND *PAUL JONES*, 1902
MAX. POWER INDICATOR CARDS TAKEN ON TRIALS.

STEAM LOG OF TORPEDO-BOAT DESTROYER No. 10, *PAUL JONES*——RUNS OVER MEASURED COURSE, SAN FRANCISCO BAY, FOR STANDARDIZATION OF PROPELLERS.

No. of run.	Time.		Speed.	Mean speed (2 runs).	Revolutions of main engine.				Steam pressures.						Vacuum.		Throttle in holes.		Temperature, in degrees.								Air pressure.	
									Gauge		Absolute.								Injection.		Discharge.		Feed.		Engine room.			
					Starboard.	Port.	Average P. and S.	Mean av. P. and S.	At engines.		1st receiver.		2d receiver.															
	M.	*S.*	*Knots.*	*Knots.*	*Per run*	*Per run*	*Per min.*	*2 runs.*	*S.*	*P.*	*S*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S*	*P.*	*S.*	*P.*
1	3	08½	19.284	19.208	704	582.5	204.752	207.978	300	300	40	24	14	9	27	26	½	½	60	60	96	83	120	120	105	90	½	½
2	3	10	19.132		741	600	211.103		280	287	45	25	14	7½	27	27	½	½	60	60	96	85	120	120	105	95	½	½
3	3	04.7	19.681	19.508	708	604.5	213.186	213.309	280	280	45	25	14	8	27	27	½	1	60	60	96	90	120	120	109	95	½	1
4	3	08	19.335		729	608.5	213.433		270	280	46	24	16	8	27	27	½	½	60	60	96	90	120	120	109	95	½	½
5	3	05½	19.623	19.557	750	571.5	214.008	211.764	270	280	45	22	15	7	27	27	½	½	60	60	96	90	120	120	109	95	½	½
6	3	06½	19.491		725	577.5	209.519		270	280	45	22	15	7	27	27	½	½	60	60	96	90	120	120	110	95	½	½
7	3	14½	18.665	18.665	755	574.5	204.803	200.451	270	280	45	20	15	7	27	27	½	½	60	60	96	90	120	120	110	95	½	½
8	3	14½	18.665		703	570	196.099		270	280	45	20	15	7	27	27	½	½	60	60	96	90	120	120	110	95	½	½
9	2	46½	21.832	21.767	704	703	253.513	253.203	260	255	50	50	18	19	27	28	½	½	65	65	86	92	98	65	98	90	1	1
10	2	47½	21.702		706	706	252.892		258	255	48	50	19	18	27	27	½	½	65	65	90	95	98	65	98	90	1	1
11	2	25	25.069	25.223	713	720	296.478	301.223	230	220	66	72	26	25	26½	27	2	1½	65	65	90	105	98	70	98	90	2	1
12	2	23½	25.376		735	726	305.968		270	260	82	75	30	28	26	26	2	1½	65	65	96	105	98	90	100	90	2½	2½
13	2	09½	28.070	28.234	702	707	326.414	330.260	270	260	110	100	44	36	26	27	2½	3	65	65	96	105	98	105	102	95	3½	3½
14	2	08	28.398		715	710.5	334.106		260	265	110	100	44	38	26	26	7	5½	65	65	96	105	98	105	102	100	3½	4
15	2	04½	29.198	28.910	694	696	334.939	336.489	265	265	110	105	44	37	26	26	7	Full	65	65	96	105	98	120	102	100	4	5
16	2	07	28.622		716	715	338.039		270	280	110	112	45	45	26	25	7	Full	65	65	96	105	98	120	102	100	5	5
17	2	09¾	28.016	25.772	687	684	316.994	308.060	258	270	95	95	38	32	26	27	2	3	65	65	96	105	98	120	102	98	3	3
18	2	34½	23.528		771	769.5	299.126		190	200	75	79	30	26	26	27	5	½	65	65	96	105	98	120	102	98	2	2
19	2	04	29.315	26.815	663	652.5	318.261	316.202	225	255	95	90	38	30	26	27	4	½	65	65	96	105	98	120	100	99	2	3
20	2	29½	24.315		788	777.5	314.143		230	260	95	90	37	30	26	27	4	3	65	65	96	105	98	120	98	102	2½	5

Runs 1 to 8, inclusive, were made July 2, 1902; runs 9 to 20, inclusive, were made July 8, 1902. Steam pressure at boiler was from 2 to 3 pounds above pressure in engine room.

The vibration of the engines at the highest speed was very slight and about the same for all three vessels. The vibration at the stern was more marked in the case of the *Perry* with propeller *A* than in the case of the *Preble* or *Paul Jones.* This vibration, however, was not excessive in any case.

In conclusion I wish to acknowledge my indebtedness to the General Manager of the Union Iron Works, Geo. W. Dickie, Esq., for the photographs accompanying this paper.

ELECTRIC TRANSMISSION OF POWER FOR NAVY YARDS.—II.

By William S. Aldrich, Member.

The power problem of the navy yard, with its legitimate expansion of work and, perchance, at any time, the construction of a naval vessel, from a torpedo boat to a battleship, at once demands a consideration of the efficiency of floor space. The yard is hemmed in by city enclosures. It is similar to many a manufacturing establishment around which the city has grown to a dense population. It cannot expand territorially. It must develop in efficiency of production, and take on larger work, or competitors will leave it in the lurch. In this connection, nothing has more truly furnished the basis of argument nor more frequently and justly been quoted in every discussion of this nature than the following remarks of Superintendent S. M. Vauclain, of the Baldwin Locomotive Works:

"If we should abandon electric driving, our manufactured product would now cost from 20 to 25 per cent. more for labor, and, furthermore, were it not for electric driving the Baldwin Locomotive Works would have to cover 40 per cent. more floor space than they now do to maintain their present output."

In these works, by the earlier system of steam distribution serving many isolated engines, it was found that 20 per cent. of the indicated horsepower of the engines was available at the machines and tools. The introduction of electric driving has effected a saving of 33⅓ per cent. of fuel and 40 per cent. of water evaporated. Owing to the intermittent nature of much of the work, it has been found that 300 horsepower of generator capacity is ample for 3,100 horsepower of nominal (or rated) electric-motor service. Elsewhere instances are on record showing an annual saving of more than 50 per cent. of the investment required to change over from the mechanical to the electric system of driving. Other manufacturers report that their output is more than doubled, and at much less working cost per unit than with the old system.

Up-to-date machines and tools are called for on every hand. It is a far cry, from Atlantic to Pacific. It is heard from maker and user alike. It is estimated that if a new machine will do additional work or save cost of labor of at least 5 per cent. of its investment, it will pay to introduce it at once. But obsolete methods of driving continue to be employed. If electric driving could not have shown from the start a greater aggregate saving than 5 per cent. on its investment, it would still be in its infancy.

Modern machine tools are made heavier in every way, with reference to the application of the American principle of intensified production—that of working the tool up to the destructive limit. They have greater weight, greater strength, and require greater powering to stand the heavier cuts and coarser feeds than the last generation of apprentices were accustomed to see. These machines will, with belt driving, as designed, turn out from 25 to 33⅓ per cent. more work in the same time. This represents probably an ultimate saving of almost as much on the original investment required to install them. Planers, for instance, are now operated at from 70 to 80 feet per minute against the 40-foot rate of the old machines. The introduction of multi-tool workshop appliances, for the simultaneous performance of several cutting operations, increases of itself the amount of work done from 25 to 50 per cent., and they earn from 10 to 25 per cent. on their investment. While iron-working tools probably show the greatest improvement, woodworkers have not been idle. They are gradually feeling the impulse in one of the most conservative lines of workshop production. With their heavier and more powerful tools, they guarantee from 25 to 50 per cent. more work per day than their older machines were in the habit of doing.

In the evolution of the modernized electrically-driven factory or mill, a few distinct stages have been successively passed, and, in general, in the following order:

(1) Isolated shops, each with main-line shafting driven by one turbine or steam engine with its individual boiler—the most uneconomical of all methods.

(2) Local generation of steam power for a large central engine and its nearby auxiliaries, consisting of small, independent, iso-

lated and scattered steam engines—a ready, but uneconomic, method of meeting expansion of business by adding departments or shops from time to time, each with its own steam engine.

(3) Concentration of the steam-boiler plant at a point economically located with reference to the engines served, but isolated engines kept in use or added as required for the extension of power—economic generation of steam combined with very uneconomic distribution of power through long steam pipes, to be used in small, isolated engines.

(4) Replacing all steam auxiliaries and steam-pipe distribution by some form of motor service supplied by power from a local (sectional) or main central power plant, using for this purpose compressed air, hydraulic pressure, wire-rope transmission or electric driving. At this stage, and for the purpose of serving the outlying districts with small power demands, the 110-volt direct-current electric motor was at once adopted and seemed to meet all requirements, especially where electric wiring and circuits for lights provided the facilities at any point for attaching motors.

(5) The proposed extension of one or the other of the preceding systems of transmission to supply all power demands and such other requirements as might be met by a single system, abolishing the local shop engines and all steam auxiliaries.

(6) The gradual extension of electric transmission and distribution from the lighting to include the power service, usually adhering to the direct-current system in existing establishments, with tentative adoption of the alternating current in a few instances, either alone or in conjunction with the direct-current service.

(7) The entire adoption of the electric drive, served from one central power plant, in small, compact works, with light machines by using the direct-current system, with constant and variable speed motors, and combined individual and group driving; in large, scattered works, with heavy tools and great variety of power service, by using the alternating current with constant-speed induction motors for individual or group driving, depend-

ing for speed variations upon the usual speed cones and change-gear trains on the machines as designed by the builders, combined with small direct-current service for cranes and hoists.

(8) The introduction of the double-current electric-drive supply of alternating and direct current as demanded for the respective services, from independent generators; in existing establishments, with direct-current service, the addition of an independent alternating-current service; in new plants, the installation of the alternating-current system for all service, directly and indirectly.

(9) The final adoption of alternating current, supplying such direct current as may be required, directly from the generators, of the double-current type, or, through transformation of alternating to direct current by rotary converters; or, from direct-current generators driven by alternating-current motors.

In the present state of the art it is inevitable but that both alternating and direct-current systems should be required in any large installation for navy-yard work. Each has its special sphere of usefulness. The entire replacement of the one by the other seems only a very remote probability. At the first, of course, the direct current held undisputed sway. Of recent years the alternating current has made steady and sure advances into the direct-current field. It may be said that in every case it has held its own where so introduced. It appears to be in the field of factory transmission to stay. For variable speed, direct-geared or direct-connected machine driving, for cranes, hoists and traction, the direct current still seems commercially desirable. Alternating-current motors can be so used, and have been in more than one instance.

Granted that both the alternating and direct-current services are at present indispensable, that the direct current will not again be in entire command of the field of factory transmission, and that the alternating current may at any time come into full possession, what type of generators should be installed in a navy-yard power plant? Clearly, either one of two cases presents a good claim:

(1) Double-current machines, generating both direct current and polyphase alternating current from the same armature, of

suitable, easily-controlled, but not independent voltages, and which machines at any time may be as effectively and as efficiently used to generate polyphase current alone for the electrical supply of all services. This type of installation has recently been made in an entirely new shipyard representing the latest American practice in all of its equipment.*

(2) Alternating-current generation and distribution, throughout the system, with the use of rotary converters for any and all direct current required. This type of installation is represented in the new equipment of the Brooklyn Navy Yard.†

For factory transmission, alternating would not be obtained from direct-current supply, by the use of inverted rotary converters. That is to say, one would not intentionally graft on an alternating to an old direct-current service. But, he would be fully justified by precedent and economy in grafting on a direct-current to an existing alternating-current system. It is inconceivable that there should ever be seriously considered the reverse of the latter arrangement—the reverse of item (2) above, namely, a direct-current installation throughout, using rotary converters, operated inverted, to supply from the direct-current input such alternating-current output as might be required in the navy yard.

The inherent difficulties of this somewhat inverted transformation are not insurmountable. They have been experimentally overcome. Rotaries have been thus operated in old direct-current installations. In such instances, a small electrical supply was required at some distant point. This condition was better met by alternating transmission from the old power plant than by a new installation at the distant point. But, this is the exception rather than the rule. It is an exception only suffered in the case of an incandescent-lamp load; that is, of an entirely non-inductive load. It would not be tolerated in a system with an induction-motor service or other inductive load.

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* "Electricity in a Modern Shipyard," by J. B. O'Hara, "Cassier's Magazine," Vol. XXII, p. 117, June, 1902.

† "Systems and Efficiency of Electric Transmission in Factories and Mills," by W. S. Aldrich, "Journal of the American Society of Naval Engineers," Vol. XII, p. 402.

Variable inductive loads, such as induction motors involve, make it almost impossible to control the speed of rotary converters when operated inverted, as above considered. Serious and costly breakdowns have occurred in such instances. By the sudden reversal of conditions, whether intentional or accidental, the armature and attached parts of the now inverted rotary have been sped up to the danger limit, analogous to fly-wheel accidents due to overspeeding. Inverted rotaries would not be used in factory transmission.

Therefore, considering in detail each of the preceding cases—(1) and (2)—it is to be noted that a definite and practically invariable ratio exists between the alternating and the direct-current voltages from the same armature. The voltage at the machine of the single or two-phase alternating current will be $\frac{1}{2}\sqrt{2}$ of the direct-current voltage at the other end of the armature; that is, about 0.707 of the direct-current voltage, whether a double-current generator or rotary converter be under consideration. In three-phase service the alternating voltage will be $\frac{1}{2}\sqrt{3} \div \sqrt{2}$, or about 0.613 of the direct-current voltage from the same armature.

The usual working voltages on so-called low-tension service, whether alternating or direct, for reasons which cannot and probably need not be explained, have come to be standardized at 110, 220, 440 and 550 volts. The 110 has been and the 220 is coming to be quite the common voltage for single-wire circuits. Only a short while ago the 110 for single wire and the 220 volts for three-wire circuits were much in vogue. The latter is not the less important, but the growing use of lamps and small motors on 220-volt circuits places this as the next step up in the rise of commercial voltages. Moreover, the 220-volt service adapts itself admirably to the use of 440 volts on three-wire system, with its 220 volts on each side of the neutral, as formerly we had the 220-volt three-wire system, with its 110 volts on each side of the neutral. In each case motors are best used across the outer wires at the higher voltages—a practice which is rapidly extending in factory installations—the 220 volts for the direct-current service, the 440 volts for the alternating-current

service. The 550 is the nominal voltage for three-phase working and direct-current traction.

Alternating and direct current from the same armature, whether on a double-current generator or rotary converter, admits of little chance of a compromise among these several commercial voltages. It would be simple, for instance, if 330 volts was a recognized standard; thus, 550 volts direct current and 330 volts three-phase alternating from the one armature of either type of machine. But, while 550-volt direct-current motors are much in evidence, no one is building motors or supplying lamps on a commercial scale for 330-volt service; nor are they likely to do so. It would not be in keeping with the strictly American method of workshop production. Probably the nearest surrender in this battle of the voltages is the use of 440-volt two-phase alternating current and 625 volts direct current, which latter voltage may be used in several such commercial machines today.

If it ever comes to turning down the direct-current service and replacing it entirely by the alternating in the same navy yard, it will be most effectively and economically done if there are no rotaries to throw out of service; that is, if, instead of rotaries, there be installed double-current generators for such direct-current work as may be required. It will then entail no loss to cease using the direct-current end of this machine at any time. The proportion of alternating and direct current delivered is regulated by the demands upon the machine automatically provided for, so that heavy demands for alternating will be allowed for by light demands for direct current. To cease using the rotary, however, as such, means a machine thrown out of service. Of course, a good rotary may be used as a double-current generator, but it is usually preferable if the machines be specially designed for their respective services.

Against this advantage of the double-current service, must be offset the use of two sets of circuits from the generating plant. This will not be a disadvantage, considering the short distances in navy-yard transmission, the desirability of central control of the distributing system, and the strategic value of two sets (or

more) of wired circuits ready for either service at any time. This practice is also in keeping with the growing custom of electrically operating the several classes of work in a manufacturing establishment on different circuits from the central power plant. Thus separate circuits, respectively, for the incandescent lamps, the arc lamps, the cranes, hoists and elevators, the industrial railway or internal traction service, and the machine tools. The latter circuits may even further be subdivided for the somewhat uniform load of the group driving and for the intermittent loads of the individual motors on machine tools. In general, the effort is to place all steady, uniform loads on related circuits; all variable loads on separate circuits. Operating electric lamps from the crane-motor circuits, for instance, would hardly be tolerated.

If the fixed-voltage ratios of the above double-current types of machines be undesirable, the only solution of the problem of double-current supply lies in the use of the independent generator, whether driven by electric motor or steam engine. In all probability the main generators would be of the alternating-current type, direct connected to steam engines, the direct-current generators to be driven by alternating-current motors. The latter would be of the induction type, if no objections were raised to slight falling off in speed of the motor, and so of the direct-current generator, with increasing loads on the latter. On the other hand, synchronous motors would be preferred, if constancy of speed were necessary under all loads within the breakdown limit.

The synchronous motor, as well as rotary converter, is now in successful use as a phase balancer. Through the over-excitation of the fields of this type of machine it may be made effective in operating like a condenser on the circuit; that is, in producing leading wattless components of the current to neutralize or balance the lagging wattless components due to the induction motors and other inductive loads on the system. Such a system of synchronous machines and induction motors may be operated without appreciable phase displacement, or with an approach to unity-power factor. This is a condition sought after in all alternating-current distribution, a condition that prevails with the

use of incandescent lamps and similar non-inductive loads, a condition in which there is no phase displacement due to the load. The whole system may therefore be operated throughout a wide range of load variations, much as if it were simply a direct-current service. The inherent advantages of such operation are at once apparent. It is the condition of best regulation. It results in maximum motor output for any given capacity of the generating plant. It is a condition altogether desirable in alternating-current working. It removes at once probably the greatest objection usually raised against the use of alternating current in factory transmission, namely, the low-power factor of the system and the inductive drop in voltage due to the type of induction motors now universally employed in such service.

A synchronous motor driving a direct-current generator admits of two very desirable features, if both kinds of current must be supplied: (1) The use of alternating and of direct-current service of independent voltage relations and ratios; (2) the use of the condenser-like action of the synchronous motor to neutralize the ever present inductive effects of the induction-motor service, so that the whole system may be operated without appreciable phase displacement, or at nearly unity power factor, an approach to the ideal condition. However, as far as the latter advantage is concerned, it may be secured as well by using the rotary or synchronous converter, similarly operated, with over-excited fields.

The synchronous motor itself may even be used to advantage in the larger types of factory transmission where absolute uniformity of speed is desired. The earlier objections to its use, that it requires direct current for its field excitation, no longer hold in the best modern installations where double-current service is at hand. When made of the revolving-field type such motors are self-starting from rest, if only lightly loaded. They may be very heavily overloaded without falling out of synchronism or out of step. A well-designed motor of this type should carry three times its normal load and not drop out of step, if operated at best field excitation, ensuring its operation as a non-inductive load on the circuit (equivalent to a direct-current

motor), and therefore producing no phase displacement. They represent the highest attainable efficiency of electric motor operation, approaching the ideal conditions of such service, in which the motor attains almost the same efficiency as the generator.

A compromise between the direct and alternating-current advocates is an urgent necessity, that there may be least scrapping of machinery and minimum loss in the event of either of them gaining the ascendency. As the business stands to-day, both kinds of service must be supplied to a navy-yard system. It is entirely possible to have electrical machinery designed and built for any service, for any voltage, but this procedure is not in line with the American system of workshop production. As far as we are at present concerned with navy-yard installations, it is evidently a simple question of finding what can be done, what it is best to do, under the given circumstances surrounding each such installation, making use, if possible, of the generators and motors on the market conforming to the acknowledged standards in capacity and voltage.

If for no other than the strategic advantages arising from standardization and duplication, it would certainly not be advisable for the Government to install such special electrical machinery. Hence arises the difficulty in selection of system and of voltage, but especially in the choice of voltage. The strategic advantage of drawing on a distant source of electrical supply in a time of public exigency would certainly dictate installing or preparing to use the alternating-current system. The military and economic advantages of transmitting large units of power, at reasonably high voltages, with quite small wires, preclude any consideration of the direct-current system, with its low voltage and massive wires. So far it is a question of transmission, should its necessity arise, from an outside base of supply to a navy-yard plant. Within the yard it may be used without other transformation than step-down in voltage, or it may be further transformed into direct current by rotary converters.

All experience in commercial electrical supply has so far shown that the distant transmission of power is best effected by the alternating current; and, that when so transmitted, it is best to

distribute and utilize the power with the least transformation of energy; that is, by further use of the alternating system. Only in very special cases is this departed from, and notably so in the case of direct-current traction from a distant source of electrical supply. In electric lighting, if the power is transmitted by the alternating current, it is similarly used, with rare exceptions, and these occur especially where an existing three-wire 110-volt direct-current lamp and motor service must continue to be thus supplied, a condition met by interconnected rotary converters. In electric-motor service, if the power is transmitted by the alternating current, it may also be said that it is coming to be the practice to so use it without further transformation into direct current.

If we consider alone any ordinary commercial machine shop, with traveling cranes, it is quite likely that the direct current would be preferred for all service, from generating plant within its walls. On the other hand, for industrial works covering several acres, with widest range of power demands, including, for instance, 100-ton punches operated by electric motors, we find that the alternating current has been successfully employed. A 25-horsepower induction motor will operate a 100-ton punch with suitable fly-wheel attachment, reducing the problem of electric driving to one simply of design and arrangement to meet the power demand of the given workshop appliance. Moreover, for extremely large and heavy work, it is the practice to install two or perhaps three induction motors of various capacities on the same machine. This allows of wide range and much variety of work, and, as nearly as practicable, simultaneous operations may be executed with no loss of time.

CONTRACT TRIAL OF TORPEDO BOAT No. 28, THE *DE LONG.*

By Lieutenant Gustav Kaemmerling, U. S. N., Member.

The U. S. torpedo boat No. 28, *DeLong*, is one of two boats built by the George Lawley and Son Corporation, of South Boston, Mass., on the same plans and specifications, the general plans and specifications being furnished by the Department. These boats were two of a number of boats authorized by Congress in an act entitled, "An act making appropriations for the Naval Service for the fiscal year ending June 30, 1899, and for other purposes." This act was approved May 4, 1898, and authorized the construction of twelve torpedo boats of about 150 tons displacement, to have the highest practicable speed.

The contract was signed September 27, 1898, the price being $159,400, and the time allowed for completion, one year. On March 20, 1900, the Department granted an extension of time for completion of twelve months to the builders of torpedo-boat destroyers and torpedo boats authorized by the Act of May 4, 1898.

The work on these boats was greatly delayed because of the inability of the contractors to obtain material.

On April 17, 1901, the Department granted a further extension of time of ten months for the completion of torpedo boats *Blakely* and *DeLong*.

The price stated above does not include ordnance, ordnance outfit, air compressor and plant, compasses, and other equipment, fittings and stores which are supplied by the Government.

The speed guaranted in the original contract was 26 knots an hour, to be maintained for two consecutive hours over a course not less than 20 nautical miles in length, the vessel, on speed trial, to carry 9 tons of ordnance, 8 tons of equipment and 10 tons of coal, or equivalent weights similarly placed, in addition to complete machinery with spare parts and engineers' stores.

It was provided in the contract that a penalty at the rate of $12,000 per knot should be inflicted in case the speed fell below 26 knots, and if a speed of 25 knots could not be reached on trial the vessel was to be rejected. The original speed requirements were modified by the Navy Department on February 26, 1902. These modifications reduced the speed to 25 knots per hour for the mean of two runs in opposite directions over a measured nautical mile, and to 24 knots to be maintained for one hour, the weighting of the boat to be the same as originally required.

The total weight of machinery and boilers, including auxiliaries—distilling plant, steam-heating plant, water in boilers, condensers, pipes and feed tanks, also stores, tools and spare parts—was limited to eighty tons, and a penalty was fixed for overweight at the rate of $200 per ton, with the further provision that if the overweight exceeded five per cent. an additional penalty of $1,000 was to be inflicted.

HULL.

Length between perpendiculars, feet	175
over all, feet	175
Beam, extreme, feet and inches	17–7
L.W.L., feet and inches	16–10⅛
Ratio of length to beam	9.95 to 1
Mean draught on trial, feet and inches	5–10
Displacement on trial, tons	196
per inch at L.W.L., tons	5.4
Area of L.W.L. plane, square feet	2,278.5
Center of L.W.L. plane aft of midship section, square feet	11.23
buoyancy above keel, feet and inches	3-2
aft of midship section, feet	1.44
Area of immersed midship section, square feet	63.4
Transverse metacenter above center of buoyancy, inches	6.33
Longitudinal metacenter above center of buoyancy, feet	620.9
Number of frames	115

The hull is constructed of mild steel of domestic manufacture, with frames spaced 18 inches apart, except where intermediate frames are placed. The outer keel plate from frame 27 to frame 96 is 10-pound plate; forward and aft of these frames it is 7½-pound plate. The shell plating abreast boiler and machinery spaces (frames 31 to 82) is 7-pound plate; forward and aft of these spaces it is 5 and 6-pound plate.

The ship is divided into eleven principal compartments by ten 'thwartship, watertight steel bulkheads extending to the sides of the vessel and to the deck. These compartments are, consecutively, the fore peak, windlass room, officers' quarters, petty officers' quarters, forward boiler room, forward engine room, after engine room, after boiler room, galley and crew's mess room, crew's quarters and tiller room. Store rooms and magazines are provided below the floors of the living spaces and below the windlass room.

The boat is fitted with a ½-inch nickel-steel conning tower forward, and a 7-pound mild-steel plate conning tower aft. In the forward conning tower the steam and hand-steering gear is located; also revolution indicator and voice pipe to forward engine room. This conning tower also contains entrance to officers' quarters, and the searchlight is placed on top of it.

The after conning tower contains hand-steering gear, voice pipe to after engine room, and entrance to crew's quarters and mess room.

Besides the voice pipes in conning towers, the various compartments of the engineering department are similarly connected, as follows: The forward engine room is connected with the forward boiler room, and the after engine room is connected with the after boiler room.

The boats carried are as follows: One 18-foot dinghy, one 14-foot dinghy, one 17-foot canvas folding boat.

Coal Bunkers.—There are eight coal bunkers, with a capacity of about 70 tons, at 43 cubic feet to the ton. In the bottoms of the two 'midship coal bunkers, alongside the engine rooms, the eight reserve feed tanks are placed. These tanks hold about 1,700 gallons of water.

The coal bunkers in the boiler rooms are fitted with watertight sliding doors, and the engine-room coal bunkers communicate with those forward and aft by means of openings provided with watertight hinged doors.

Escape rungs are fitted in each coal bunker leading to the bunker openings in the deck.

Drainage.—The drainage systems are as follows:

(1) A 5-inch drain pipe connected to the after circulating pump, having suctions and valves in after engine and after boiler rooms; a 5-inch drain pipe connected to the forward circulating pump, having suctions and valves in the forward engine room and forward boiler room.

(2) A 2½-inch drain pipe connected to both fire and bilge pump and to the auxiliary feed pump, from which suctions lead to each compartment except forward collision compartment and tiller compartment; these two compartments are sluiced into compartments next to them.

(3) A system of steam ejectors, with separate connections to each of the compartments in the boiler and machinery spaces and also in petty officers' and crew's quarters spaces.

A series of limber holes in the vertical keel allows water to drain from side to side.

ARMAMENT.

The battery consists of three long 1-pounder rapid-fire guns, mounted on deck, one on each side, immediately aft of forward conning tower, and one on the center line of ship aft of after conning tower. There are three tubes for torpedoes situated on deck, one on each side, just forward of the center, and one on the stern.

The original design called for three 3-pounder, quick-firing, semi-automatic guns, located as above. The change in battery requirements was made at same time change in speed requirement was made, the Department still insisting, however, that contractors must run the official trial with weights on board equal to those required by original armament.

The Department decided at the same time that the two spare torpedoes which were originally specified would not be required, though their equivalent weight must be carried on the official trial.

MAIN ENGINES.

There are two vertical, inverted, direct-acting, four-cylinder, triple-expansion engines, placed in separate watertight compartments, the starboard engine being forward of the port, each engine having the high-pressure cylinder forward.

The high and intermediate-pressure cylinders are in one casting, and, together with the two low-pressure cylinders, are supported by eight forged-steel columns.

The main valves are of the single-ported piston type, there being one for each cylinder. The I.P. and both L.P. valves are provided with balance pistons, the cylinders for which form part of the upper covers of the valve chest. The H.P. and I.P. valves are plug valves, and the L.P. valves have spring rings.

Live steam connection is made with the I.P. and L.P. receivers. The auxiliary exhaust has a connection with the condenser, the L.P. receivers and the atmosphere.

The valve gear is of the Stephenson link type, with double-bar links and crossed rods. Provision is made on each cylinder for an adjustment of cut-off by means of a sliding block in reverse-shaft arm, which block can be moved by hand-screw gear.

The main pistons are steel forgings, dished, and each is fitted with two packing rings $\frac{5}{8}$ inch wide and $\frac{7}{16}$ inch thick. The piston rods and connecting rods are of forged steel. The crossheads are of forged steel, in one piece with piston rods, the ahead sides of sliding faces being fitted with white metal. The go-ahead crosshead guide is of cast iron, bolted to forged-steel strongbacks, which are in turn bolted to the engine columns. The guide is cast hollow, for the circulation of water.

The backing guides are of composition and bolted to the face of the go-ahead guide.

The eccentrics are forged on the shaft. The eccentric straps are of composition, faced with white metal, and the eccentric rods are of forged steel.

The valve stems and valve-stem crossheads are of steel, forged in one piece, and take hold of the link blocks directly.

Each engine bed plate consists of five cast-steel bearers bolted to two forged-steel plates running fore and aft, which, in turn, are bolted down and held by body-bound bolts to fore-and-aft engine keelsons.

The reversing gear consists of a steam cylinder connecting directly to an arm fixed on the reversing shaft. The valve of the steam reversing cylinder is of the common slide-valve type

worked by a system of differential levers, the primary motion being derived from the hand lever at the working platform, and the secondary motion from an eccentric on the reverse shaft.

The end of the reversing shaft is fitted to receive a hand lever for reversing engines by hand. The turning gear consists of a worm and wormwheel attached to coupling on after end of engine and is operated by means of a ratchet lever.

Each engine is fitted with a double-poppet throttle valve bolted to flange on connecting pipe between top and bottom of H.P. steam chest. Each throttle lever is provided with a latch, and a worm gear for fine adjustment.

MAIN ENGINE DATA.

Cylinders, number for each engine	4
H.P., diameter, inches	14
I.P., diameter, inches	22
L.P. (2), diameter, inches	25½
Stroke, inches	18
Valves, H.P. (1 for each cylinder), diameter, top, inches	7$\frac{3}{4}$
bottom, inches	7½
I.P. (1 for each cylinder), diameter, top, inches	14$\frac{3}{4}$
bottom, inches	14½
L.P. (1 for each cylinder), diameter, top, inches	16$\frac{3}{4}$
bottom, inches	16½
Side of valve on which steam is taken:	
H.P.	Outside.
I.P.	Inside.
L.P. (both)	Outside.
Balance pistons, H. P., diameter	None.
I.P., diameter, inches	4¾
L.P. (each), diameter, inches	4¾
Valve stems, H.P., diameter, inches	1⅝
I.P., diameter, inches	1⅝
L.P., diameter (each), inches	1⅝
Main steam pipe, diameter, inches	5½
exhaust pipes (two), diameter, inches	10
Piston rods, diameter, inches	3
of axial hole, H.P. and I.P., inches	1$\frac{3}{16}$
L.P., inches	2
Connecting rods, center to center, inches	40
section at upper end, H.P. and I.P. (each), inches	1¾ x 3¾
L.P. (each), inches	1½ x 3
section at lower end, H.P. and I.P. (each), inches	1 x 5
L.P. (each), inches	⅞ x 4¼

Crank pins, H.P. and I.P., inches	6¾ x 9
L.P. (each), inches	6¾ x 7
Crank-pin bolts (2), diameter, inches	1⅞
Crosshead pins, H.P. and I.P., inches	3⅜ x 5¼
L.P. (each), inches	3⅜ x 4½
axial hole, diameter, inches	1½
Crossheads, wearing surface, H.P. and I.P., ahead, inches	13½ x 7½
L.P., ahead, inches	11½ x 6½
H.P. and I.P., backing (2), each, ins.	13½ x 2¾
L.P., backing (2), each, inches	11½ x 2¼

Shafting and Bearings.—The crank, line and propeller shafting is hollow and of forged steel. The crank shaft of each engine is in one forging, the eccentrics being part of shaft. The cranks of the H.P. and I.P. cylinders are opposite each other, as are also the 1st and 2d L.P. cranks, the first two being at right angles with the last two. The sequence of the cranks for ahead motion is H.P., 1st L.P., I.P., and 2d L.P. The line shafts are supported by spring bearings and the propeller shafting by struts, the latter being encased in brass sleeves at bearings. The stern-tube shafting is also encased in a brass sleeve where it passes through stern tube.

Each thrust bearing is of cast steel, made in halves, and lined with white metal. The thrust is taken by two 2-inch steel bolts screwed into the aftermost of the engine bearers, and secured to the thrust bearing by means of nuts on either side of the bosses provided for that purpose on the bearing.

Main Condensers.—There are two main condensers, one for each engine. The shells are of Muntz metal plate stiffened with tee and angle rings. The water chests are of copper and tube sheets are of Muntz metal. The tubes are of Muntz metal, tinned inside and out, and are screwed into the tube sheet at one end, the other end being provided with screw glands. The circulating water passes through the tubes. A baffle plate with holes is fitted to direct the steam over all the tubes. A direct-connected, centrifugal pump furnishes circulating water when the boat is not under way. When running, water is forced through the condensers by the speed of the boat, scoops with strainers being fitted over the injection openings.

MAIN CONDENSER DATA.

Diameter, feet and inches	3-1
Thickness	No. 10 B.W.G.
Number of tubes	1,261
Length between tube sheets, feet and inches	6-2
Diameter of tubes, inch	$\frac{5}{8}$
Thickness of tubes	No. 18 B.W.G.
Cooling surface, each condenser, square feet	1,241
total, square feet	2,482
Ratio total cooling to total heating surface	1 to 3.05
Diameter of circulating-pump runner, inches	18
Width of circulating-pump runner, inches	$1\frac{1}{2}$
Diameter of inlet nozzle of circulating pump (2), each, inches	7
outlet nozzle of circulating pump, inches	9
Size of circulating engine, single cylinder, slide valve, stroke, ins.	4 x 3

Main Air Pumps.—For each engine there is a double-acting, center-suction air pump of the Bailey type, worked through a rocker by an eccentric on main shaft. The pump valves are made of manganese-bronze.

Main Circulating Pumps.—For each condenser there is a centrifugal, double-inlet circulating pump which is arranged to draw from the sea, its engine room and adjacent fire-room bilge, and to discharge into the condenser. It is driven by an independent, vertical, single-cylinder engine. Each pump is capable of discharging 750 gallons of water per minute from the bilge.

Screw Propellers.—The propellers are of manganese-bronze, tinned, each having four blades. They are true screws, the starboard one being left-handed and the port one right-handed. Each propeller is secured on its shaft by a single key and a composition cap nut screwed on and locked in place.

Number of blades	4
Diameter, feet and inches	5-6
Length of hub, inches	$12\frac{1}{2}$
Mean pitch, feet and inches	9-6
Helicoidal area, square feet	10.86
Projected area, square feet	7.33
Disc area, square feet	23.76
Ratio of diameter to mean pitch	1 to 1.73
Weight, complete, pounds	775

BOILERS.

There are three water-tube boilers of the Normand type, two of which are located in the watertight compartment immediately forward of the engine rooms, and the third in the watertight compartment immediately abaft the engine rooms.

There is one furnace with two doors under each boiler. These furnaces are lined with firebrick. The grate bars are of mild steel. The casing is of thin sheet iron, lined with magnesia and asbestos, with one uptake and smoke pipe for each boiler.

Each boiler is placed in saddles built in the boat under the bottom drums. Each boiler has one twin 3½-inch spring safety valve placed on the stop-valve nozzle.

The main feed water is discharged through brass pipes connected with a Thornycroft feed-water regulator, and the auxiliary feed is discharged through a separate pipe, both leading into the down-take pipes at the front of the boiler.

BOILER DATA.

Steam pressure designed, pounds	250
Number of boilers	3
Width over casing, feet and inches	10–8
Height, feet and inches	10–8
Steam drum, length, feet and inches	10–6
diameter, inside, inches	32
thickness, inch	7/16
where drilled for tubes, inch	7/8
Water drums, number for each boiler	2
diameter inside, inches	16
thickness, inch	5/8
Furnaces, number each boiler	1
width of grate, feet and inches	6–5
length of grate, feet and inches	7–9¾
doors, each furnace	2
Tubes, diameter, inches (O.D.)	1¾
number in each boiler	1,244
thickness	No. 11 B.W.G.
Grate surface, three boilers, square feet	150
Heating surface, three boilers, square feet	7,575
Ratio grate surface to heating surface	1 to 50.5
Smoke pipes, number	3
dimensions, inches	24 x 36
area of each, square feet	5.14
height above grates, feet and inches	20–2
Ratio of smoke-pipe area to grate area	1 to 9.73

OTHER MACHINERY.

Forced Draft.—The closed fire-room system of forced draft is used, air being supplied by three blowers located, two in the forward fire room and one in the after fire room. These blowers are placed with their shafts vertical immediately below the ventilator through which the air is taken.

Each fan is driven by a direct-connected double engine having piston valves and cranks at 180 degrees. Cylinders, diameter, 4 inches; stroke, 3 inches. Fan, diameter, 42 inches; width at rim, 12 inches. Area of induction nozzle, 452 square inches; area of eduction nozzle, 1,582 square inches.

Ash Ejectors.—There is one Davidson hydraulic ash ejector in each fire room.

Feed Pumps.—There are two main and one auxiliary feed pumps of the Davidson type, all of the same size, each pump having one 10-inch by 12-inch steam cylinder and 6-inch by 12-inch water cylinder, with a capacity of 147 gallons at 100 feet piston speed.

The main feed pumps are located, one in the forward fire room and one in the after engine room, and draw from the hot wells, communicating pipe of reserve feed tanks and adjacent air-pump channel way, and deliver to the boilers and reserve feed tanks.

The auxiliary feed pump is located in the forward engine room. This pump has a suction from the forward hot well, the communicating pipe of reserve feed tanks, the forward air-pump channel way, the sea and the drainage system, and discharges into the boilers, fire main and overboard. The discharge pipes from the main and auxiliary feed pumps to the boilers are independent pipes and check valves.

Fire and Bilge Pumps.—In the after engine room there is a vertical Davidson fire and bilge pump, with 6-inch by 12-inch steam cylinder and 6-inch by 12-inch water cylinder, which draws from the sea, bilge and drainage system and delivers into the fire main, ash-ejector main and overboard. It has a capacity of 147 gallons at 100 piston speed.

Water Service and Distiller Circulating Pump.—In the after fire room there is a vertical Davidson pump which draws from the

sea and delivers into the water-service pipes and the distiller circulating pipes. It has a capacity of 50 gallons per 100 feet piston speed. The steam cylinder is 3½ inches by 4 inches, and the water cylinder is 3½ inches by 4 inches.

Feed Tanks.—There is a feed tank of 64 gallons capacity in each engine room. This tank is fitted with a compartment filled with a filtering material through which the water from the air pump is delivered to the feed-pump suctions. Each tank has three manhole plates near the bottom, and also a cover which is removable. Each is fitted with a thermometer, water-gauge glass, and a copper ball float so arranged that it will operate a valve in the steam pipe to the adjacent main feed pump, thus maintaining a constant water level in tank.

Each tank has the following pipe connections: A discharge pipe from the air pump. An overflow gooseneck pipe leading on the inside from near the bottom of tank, with its outside end above top of tank, so arranged that any water passing through it into the bilge may be seen; this provides an overflow without a cumbersome relief valve and still prevents the discharge of vapors into the engine room. A suction pipe to feed pumps. Discharge pipes from traps. A vapor pipe opening to escape pipes.

Steam Traps.—The separators in the main and branch steam piping are all connected with automatic traps which discharge into the feed tanks.

Distilling Apparatus.—In the after fire room there are two Davidson evaporators and one Davidson distiller, the specifications requiring of the evaporators a combined capacity of 2,000 gallons of water at 90 degrees Fahrenheit in 24 hours. The water-service pump is also used for the distiller circulating pump. There is one Davidson evaporator feed pump which may also be used as a brine pump; size of cylinders, 3 inches by 1¾ inches by 4 inches.

Steering Gear.—The steering engine is located in the forward conning tower and has two cylinders 3¾-inch diameter by 4-inch stroke, with cranks at 90 degrees. This engine operates, through a worm and a system of gearing, a rack, the ends of which are connected to the quadrant on tiller by wire ropes. The valve

controlling this engine is operated by the steering wheel, which wheel may be used for direct hand steering by throwing out a clutch. With the steam gear the helm can be put from hard over to hard over in eleven seconds.

Steam Windlass.—There is a steam windlass built by the Hyde Windlass Company, of Bath, Maine, situated on a platform in the forward end of the ship. It has a double engine, with cylinders 3¼ inches by 4 inches and cranks at 90 degrees. The windlass is provided with two drums, each capable of holding 75 fathoms of $\frac{9}{16}$-inch wire cable, and is connected with a capstan situated on deck.

Air Compressor.—There is one air compressor made by E. W. Bliss, Type II, for torpedoes, located in the after engine room.

Telegraphs and Revolution Indicators.—There is a Corey mechanical telegraph in each engine room connected to transmitters in each conning tower.

Mechanical tell-tales are fitted in each conning tower to show the direction of the revolutions and relative speeds of the main engines. In each engine room there is also a mechanical indicator to show the relative speeds and direction of the revolutions of the main engines. The mechanical tell-tales are operated by a separate line of shafting from each main engine, which extends throughout the boat from the forward to the after conning tower.

Each engine-room indicator has two hands revolving in the same direction, a red one which turns with the port engine and a green one which turns with the starboard engine. These hands can be shifted on their spindles so as to be brought into coincidence when desired.

Revolution Counters.—In each engine room there is a positive-motion revolution counter which is operated from an independent shaft engaging with the main crank shaft.

Each engine room is connected with the adjacent fire room, and both engine rooms are connected together by a mechanical repeating telegraph for transmitting engine and fire-room signals.

ELECTRIC-LIGHT PLANT.

Current for the lighting system is supplied by a generating set made by the General Electric Company, consisting of a 2½-kilo-

watt dynamo of multipolar type, with a capacity of 31 ampères at 80 volts, located in the forward engine room.

The dynamo is direct-connected to a 3-inch by 3-inch engine, with piston valve and flywheel governor, designed to run at 800 revolutions per minute with full load, both being mounted on one base.

The switchboard, containing instruments and switches controling the different circuits, is located immediately over the generator on bulkhead between engine rooms. A searchlight is located on top of the forward conning tower. Portable lights with flexible connections are provided for magazines and store rooms, in addition to fixed lights in living and machinery spaces. Electric connections are furnished for running and signal lights, these also being arranged to burn oil.

TRIALS.

SCHEDULE OF CONTRACTORS' AND OFFICIAL RUNS MADE BY TORPEDO BOAT NO. 28, "DELONG."

1st contractors' preliminary run, May 31, 1901, at Boston.
2d contractors' preliminary run, June 3, 1901, at Boston.
3d contractors' preliminary run, June 15, 1901, at Boston.
4th contractors' preliminary run, June 18, 1901, at Boston.
5th contractors' preliminary run, October 15, 1901, at Boston.
1st official trial (standardization), November 9, 1901, at Newport, R. I.—This trial was unsuccessful because of carrying away of discharge pipe from air pump to feed tank in after engine room, and boat was taken back to South Boston for repairs.
6th contractors' preliminary run, April 15, 1902, at Newport, R. I.
7th contractors' preliminary run, April 17, 1902, at Newport, R. I.
8th contractors' preliminary run, April 19, 1902, at Newport, R. I.
9th contractors' preliminary run, April 23, 1902, at Newport, R. I.
10th contractors' preliminary run, April 25, 1902, at Newport, R. I.
11th contractors' preliminary run, April 28, 1902, at Newport, R. I.
12th contractors' preliminary run, May 6, 1902, at Newport, R. I.
13th contractors' preliminary run, May 8, 1902, at Newport, R. I.
14th contractors' preliminary run, May 14, 1902, at Newport, R. I.
15th contractors' preliminary run, May 16, 1902, at Newport, R. I.
16th contractors' preliminary run, May 20, 1902, at Newport, R. I.
2d official trial (standardization), May 29, 1902, at Newport, R. I.—Successful.
3d official trial (one hour), May 30, 1902, at Newport, R. I.—Successful.

Contractors were granted permission to have the boat run its trial by the standardization method, instead of making the hour's run over a long measured course.

The dates of official runs are given above. The standardization run was made on a day of favorable conditions, while there was much wind and considerable sea on the day of making the official hour's run.

The standardization run was made over the measured mile laid off at Newport, R. I. The hour's run was made in Narragansett Bay. The slowing down towards the end of the hour's run was due to some of the foundation bolts working loose on the forward air pump. Notwithstanding this, the boat made the required speed.

When running on the measured mile three observations were taken on each run to insure an average reading.

The deck counters were thrown in at the beginning of, and out at the end of, each run.

The observations on the hour's run were taken at ten-minute intervals, the deck counters being read every five minutes. All automatic stop valves were tried before each official, as well as contractor's, run.

The coal used during the trials was picked Pocahontas coal, being weighed in bags.

Because of experience on preliminary runs and the observations and action of the trial board on unsuccessful standardization run, the engine foundations were stiffened.

By the changing of trim, bringing the boat down forward, the point of excessive vibration was transferred from the forward bulkhead of the forward engine room to the after bulkhead of the after engine room.

The greatest difficulty this and, I believe, similar boats had to contend with was to make the required speed with a displacement much in excess of that of the original design in accordance with which the boats were powered.

The cause of this may lie in the overlooking of the real purpose of the torpedo boat in attempting to make them satisfy too many conditions.

If a torpedo boat makes an attack singly the chances are very much against its escaping, although it may have performed its mission. When an attack is made by a fleet of torpedo boats the chances are that a large percentage of them will be destroyed, although the mission may have been successfully carried out.

They might be classed as a large dirigible torpedo, to be expended, and that version is generally accepted, I believe, for the crews, in making an attack, are generally considered to have practically no chance for escape from destruction.

They should be, therefore, constructed with this in view. Torpedo boats have never had a thorough test in warfare, and therefore the theory advanced is admissible.

The experience at Santiago, where the enemy's destroyers were put out of action so quickly, would tend to show that there is some foundation for the above theory.

When a boat is designed for 165 tons displacement and powered, accordingly, to produce a fixed speed, it is unfair to the machinery and the scantlings of the boat, which are designed on the lightest possible lines, to produce and endure the strain resulting from the extreme speed in spite of the excessive displacement of 196 tons.

During the conduct of the various contractors' and official trials I have always felt that the test of a torpedo boat, compared with what it should be, was analogous to running a thoroughbred race horse of the most sensitive organism, carrying cavalryman and full campaign accoutrements, against another race horse carrying a jockey with a pistol only. Then, to carry the analogy further, the service frequently required of it, as compared with that of a cruiser, can be readily likened to loading a race horse with a cavalryman and all campaign accoutrements, with the expectation of having him, so loaded, go through a campaign alongside a regular cavalry mount.

In the conduct of war the Navy is said to have the advantage of having its commissary department always with it. A great deal of the requirements put upon torpedo boats to make them absolutely independent must eliminate what has generally been considered the first requirement of a torpedo boat, namely, speed.

It would seem, then, that they should always act from a base, be it a shore station or a ship. Should independent action be required of any boat far removed from a base, such hardships as would ensue from the lack of heavy bath tubs, marble-slab wash basins, various subdivided officers' quarters, all fitted with wood trimmings, a heavy cooking range and other heavy equipments in galley and elsewhere, could be dispensed with, and without unbearable inconvenience under campaign conditions.

To sum up, a torpedo boat should be constructed to operate from a base, and not be equipped similar to a cruiser.

If the boats, however, for practice in peace times are to be equipped with all the conveniences of a cruiser, then that condition should be met by not requiring all such unnecessary weights on trial runs and subjecting the boats and machinery to distressing strains on account of attempting to attain great speeds when excessively weighted.

Having established the boats' capacity for speed with regular war equipment, let them then have placed on board the various fittings necessary to make them comfortable for living quarters, so that they may be used during peace times as practice boats but not as speed record breakers.

The crew was originally almost totally unfamiliar with the work required in making such runs as were required of these boats, but was, by many changes and continual drilling, brought to a high state of efficiency.

When making the standardization runs the various speeds were obtained by a fixed pressure at the H.P. chest, the speeds corresponding to various speeds having been determined on preliminary runs.

Plates Nos. 1 and 2 represent combined cards of the highest horsepower indicated, taken on the fifth preliminary run.

Plate No. 3 represents speed curves for official standardization run. The highest south-run point is so far below the revolutions of the corresponding north-run point because the automatic stop valves on boilers Nos. 2 and 3 closed towards the end of this run, causing engines to slow down very much.

A recurrence of this has been forestalled by making the automatic stop valve proper heavier.

The average of the two runs with and against the tide was more than the minimum required over the measured mile, and the 24-knot point was well enough defined to make the curve available.

The displacement on these runs was somewhat less than on the official trials.

WEIGHTS OF *DE LONG*.

Group.		*Pounds.*
1.	Main engine cylinders	13,668
2.	Shafting	15,767
3.	Main engine framing and bearings	10,101
4.	Reciprocating parts main engines	3,634.9
5.	Main engine valve gear	3,500.7
6.	Main condensers	7,723
7.	Main air and circulating pumps	3,184
8.	Propellers	1,538
9.	Boilers	48,920
10.	Boiler fittings	20,229.8
11.	Smoke pipes	1,680
12.	Steam and exhaust pipes and valves	9,328
13.	Suction and discharge pipes and valves	8,634
14.	Lagging and clothing	3,499
15.	Flooring, gratings, etc	3,046
16.	Auxiliaries	6,757.4
17.	Fittings and gear	4,327
18.	Water	16,600
19.	Stores, tools, spare parts, etc	12,423.4
20.	Distilling and heating plants	4,755
21.	Miscellaneous machinery, etc	7,448

TABLES OF OFFICIAL STANDARDIZATION TRIAL.

ON DECK DATA OFFICIAL STANDARDIZATION TRIAL OF TORPEDO BOAT NO. 28, "DELONG," NEWPORT, R. I., MAY 29, 1902.

Run No. and direction.	Time on course.		Revolutions on course.		Mean Rev's per minute.		Speed.	Mean slip.
	m.	*s.*	*Stbd.*	*Port.*	*Stbd*	*Port.*	*Knots.*	*Per cent.*
1. South	2	50.3	801	812	282.2	286.1	21.14	19.9
2. North	2	51.8	806	822	281.5	287.1	20.95	20.7
3. South	2	33.4	809	822	316.8	321.9	23.50	20.8
4. North	2	35.4	819	835	316.2	322.4	23.16	23.6
5. South	2	24.9	832	854	344.5	353.6	24.85	23.4
6. North	2	26.7	834	863	341.1	353	24.54	23.9
7. South	2	21.6	829	839	351.3	355.5	25.42	22.6
8. North	2	20.5	853	868	364.3	370.7	25.62	25

NOTE.—Slip is based on mean pitch of 113 inches.

ENGINE-ROOM DATA.—OFFICIAL STANDARDIZATION TRIAL OF TORPEDO BOAT No. 28, "DELONG," NEWPORT, R. I., MAY 29, 1902.

Run No.	Time.	Steam pressure.				Vacuum, inches.	Injection, degrees.	Discharge, degrees.	Hot well, degrees.
		Auxiliary.	H.P.	I.P.	L.P., lbs.				
		Starboard (Forward) Engine.							
1	.....	260	135	39	1	26.90	56	86	90
		264	135	39	1	26.80			
		255	135	39	1	26.80			
2	.....	262	136	39	1	26 80	56	86	88
		260	137	38	...	26.80			
		268	135	39	1	26.80			
3	.....	263	175	54	5	26	56	88	94
		260	175	54	5	26.10			
		264	176	54	5	26			
4	.....	260	175	54	5	26.10	56	88	96
		263	175	54	6	26.10			
		263	175	54	5	26.10			
5	.....	265	205	65	9	25.50	56	90	102
		270	215	67	9	25.60			
		270	215	67	9	25.40			
6	.....	265	215	67	9	25.50	56	90	108
		267	215	67	10	25.50			
		270	217	68	10	25.50			
7	.....	253	247	82	15	24.20	56	90	112
		246	245	85	14	24.20			
		Falling rapidly.							
8	.....	275	240	78	14	24.50	56	98	112
		270	240	78	15	24.10			
		262	245	100	15	23.20			
		Port (After) Engine.							
1	7.45	261	120	35	...	27	58	90	99
		263	120	35	...	27.20	56	90	100
		263	120	35	...	27	56	90	100
2	7.52	260	120	35	...	27	56	86	100
		260	120	34	...	27.40	56	86	100
		260	122	35	...	27.20	56	86	100
3	7.59	265	160	50	1.5	27	56	86	103
		260	160	50	1.5	27	56	86	103
		260	160	50	1.5	27	56	86	103
4	8.06	260	160	50	1.5	27	56	84	104
		257	163	50	1.5	26.80	56	84	102
		260	160	50	1.5	27	56	84	102
5	8.11	265	200	63	6	26	56	86	108
		270	200	63	6	26.50	56	88	108
		265	200	63	6	26 50	56	88	108
6	8.18	270	200	64	6	26.50	56	88	104
		270	200	63	6	26.50	56	88	104
		265	200	63	6	26.50	56	88	104
7	.....	240	230	70	10	25.50	56	90	104
		235	220	65	10	25.50	56	90	104
		235	200	62	10	25.50	56	90	104
8	.....	270	222	73	9.5	25.50	56	90	103
		265	230	77	10.5	25.50	56	90	103
		260	230	77	10.5	25.50	56	90	103

ENGINE-ROOM DATA, OFFICIAL ONE-HOUR RUN OF TORPEDO BOAT NO. 28, "DELONG," NEWPORT, R. I., MAY 30, 1902.

Time.	Steam pressure.				Vacuum, inches.	Injection, degrees.	Discharge, degrees.	Hot well, degrees.
	Auxiliary.	H.P.	I.P.	L.P., lbs.				
			Starboard (Forward) Engine.					
9·00	255	215	67	10	25	54	90	102
9·10	260	215	67	10	25.60	56	90	104
9·20	265	215	67	10	25	57	92	104
9·30	262	195	61	10	15.70	57	110	80
9·40	265	195	62	10	12.50	57	112	78
9·50	257	190	62	10	11.20	57	114	78
10·00	260	200	66	13	3	57	120	78
			Port (After) Engine.					
8·59	250	203	65	5·5	26	54	88	106
9·09	260	200	63	5·5	26	56	87	104
9·19	263	195	60	6	26	57	90	104
9·29	265	203	65	7	25.50	57	91	105
9·39	260	212	67	8	25.50	56	91	105
9·49	260	220	72	9	25.20	56	91	107
9·59	255	240	80	11.5	24.70	56	94	117

ON-DECK DATA OFFICIAL ONE-HOUR RUN OF TORPEDO BOAT NO. 28, "DELONG," NEWPORT, R. I., MAY 30, 1902.

Time.	Counter.		Revolutions in interval.		Mean revolutions per minute.	
	Starboard	*Port.*	*Starboard.*	*Port.*	*Starboard.*	*Port.*
8·59	115,500	124,300				
9·04	117,176	126,005	5m. 1,676	5m. 1,705	335.2	341
9·09	118,873	127,745	5m. 1,697	5m. 1,740	339.4	348
9·14	120,563	129,465	5m. 1,690	5m. 1,720	338	344
9·19	122,242	131,180	5m. 1,679	5m. 1,715	335.8	343
9·24	123,995	132,900	5m. 1,753	5m. 1,720	350.6	344
9·29	125,545	134,600	5m. 1,550	5m. 1,700	310	340
9·34	127,017	136,315	5m. 1,472	5m. 1,715	294.4	343
9·39	128,574	138,050	5m. 1,557	5m. 1,735	311.4	347
9·44	130,124	139,785	5m. 1,550	5m. 1,735	310	347
9·49	131,657	141,540	5m. 1,533	5m. 1,755	306.6	351
9·54	133,199	143,295	5m. 1,542	5m. 1,755	308.4	351
9·59	134,697	145,085	5m. 1,498	5m. 1,790	299.6	358
			Below is result for one hour.			
8·59	115,500	124,300	60m. 19,197	60m. 20,785	319.95	346.42
9·59	134,697	145,085				

Mean revolutions per minute of both engines for one hour, 333.185.

OFFICIAL ONE-HOUR TRIAL OF TORPEDO BOAT NO. 28, "DELONG," NEWPORT, R. I., MAY 30, 1902.—AIR PRESSURES IN FIRE ROOMS IN INCHES OF WATER.

Time.	Pressures.		Time.	Pressures.	
	Forward.	Aft.		Forward.	Aft.
9·00	2	2	9·32.5	1.7	1.2
9·02.5	1.8	2.6	9·35	1.8	1.2
9·05	1.9	3.2	9·37.5	1.8	1.2
9·07.5	1.2	3.7	9·40	1.7	.8
9·10	1.1	2.9	9·42.5	1.6	.8
9·12.5	.9	3	9·45	1.3	1.8
9·15	1.6	2.2	9·47.5	1.7	1.3
9·17.5	1.4	3	9·50	1.8	4.3
9·20	1.4	2.1	9·52.5	1.5	2.6
9·22.5	1.5	2.4	9·55	1.9	1.5
9·25	1.5	1.9	9·57.5	...	.4
9.27.5	1.5	2.4	10·00	...	...
9.30	1.5	1.5			

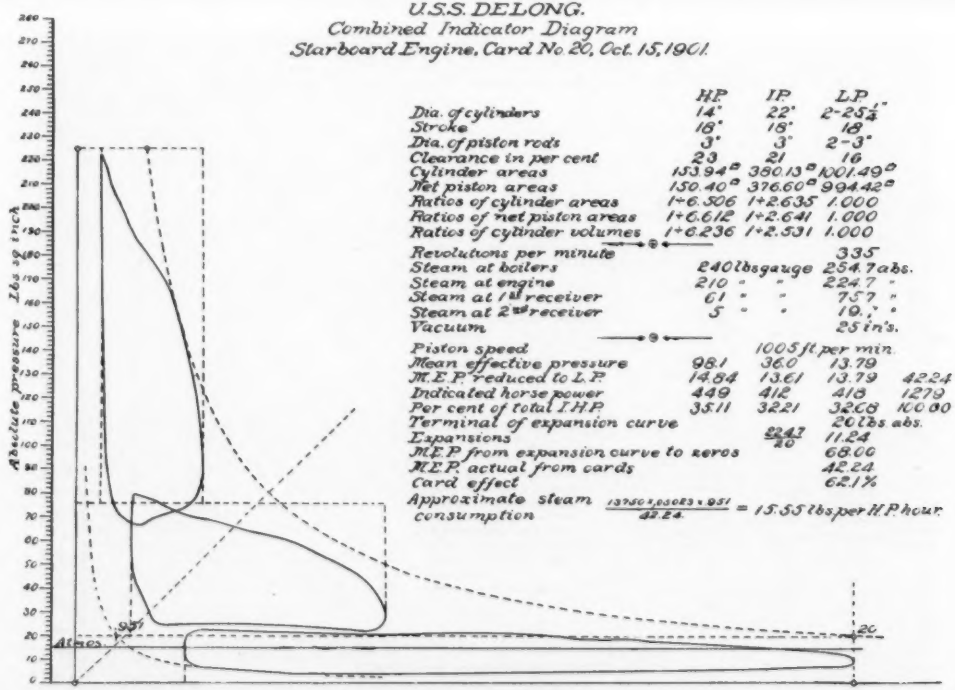
OFFICIAL STANDARDIZATION TRIAL OF TORPEDO BOAT NO. 28, "DELONG," NEWPORT, R. I., MAY 29, 1902. AIR PRESSURES IN FIRE ROOMS IN INCHES OF WATER.

No. run.	Time.	Pressures.	
		Forward.	Aft.
1	7·46	·5	·4
	7·47	·5	·4
	7·48	1	.6
2	7·52	·7	·5
	7·53	.8	·5
	7·54	1.1	·4
3	7·59	1.2	·5
	8·00	1	.6
	8·01	1.6	1
4	8·06	·9	1
	8·07	2	1.4
	8·08	2.1	·7
5	8·12	2.9	1.4
	8·13	2.3	·4
	8·14	1.9	·9
6	8·18	2.4	1.1
	8·19	2.3	1.2
	8·20	2.5	1
7	8·24	2.5	2.6
	8·25	3.5	2.8
	...	...	...
8	8·35	1.8	2.3
	8·36	2	3.8
	...	...	...

U.S.S. DELONG.

Combined Indicator Diagram

Starboard Engine. Card No 20, Oct. 15, 1901.



	H.P.	I.P.	L.P.	
Dia. of cylinders	14"	22"	2-25¼"	
Stroke	18"	18"	18"	
Dia. of piston rods	3"	3"	2-3"	
Clearance in per cent	23	21	16	
Cylinder areas	153.94□"	380.13□"	1001.49□"	
Net piston areas	150.40□"	376.60□"	994.42□"	
Ratios of cylinder areas	1+6.506	1+2.635	1.000	
Ratios of net piston areas	1+6.612	1+2.641	1.000	
Ratios of cylinder volumes	1+6.236	1+2.531	1.000	
Revolutions per minute			335	
Steam at boilers	240 lbs gauge		254.7 abs.	
Steam at engine	210 " "		224.7 "	
Steam at 1st receiver	61 " "		75.7 "	
Steam at 2nd receiver	5 " "		19.7 " "	
Vacuum			25 in's.	
Piston speed		1005 ft per min.		
Mean effective pressure	98.1	36.0	13.79	
M.E.P. reduced to L.P.	14.84	13.61	13.79	42.24
Indicated horse power	449	412	418	1279
Per cent of total I.H.P.	35.11	32.21	32.68	100.00
Terminal of expansion curve			20 lbs abs.	
Expansions		224.7/20	11.24	
M.E.P. from expansion curve to zeros			68.00	
M.E.P. actual from cards			42.24	
Card effect			62.1%	

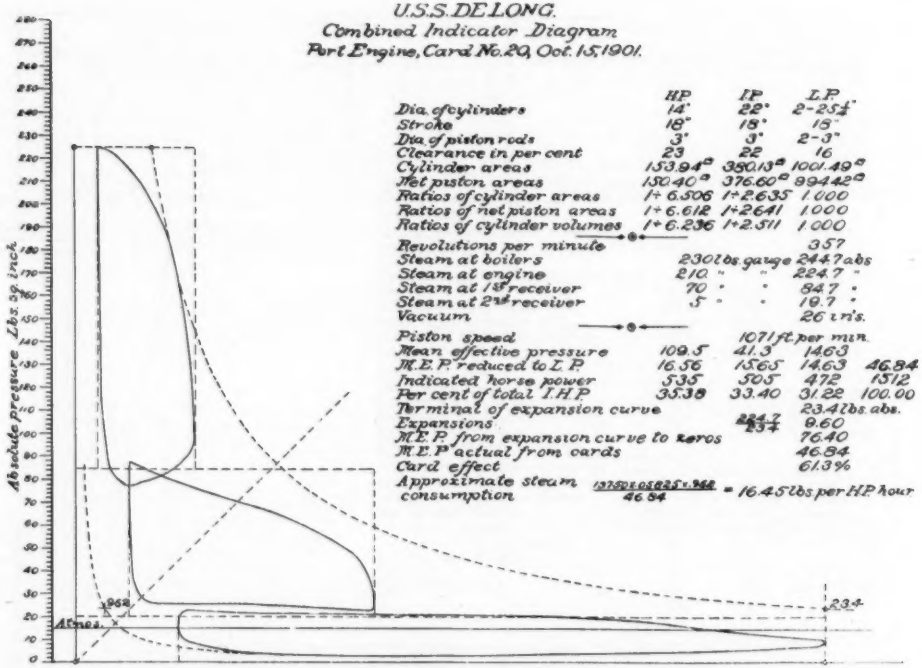
Approximate steam consumption $\frac{13750 \times .0023 \times .951}{42.24} = 15.55$ lbs per H.P. hour.

PLATE NO. 1.

U.S.S. DE LONG.

Combined Indicator Diagram

Port Engine, Card No. 20, Oct. 15 1901.



	HP	IP	LP	
Dia. of cylinders	14"	22"	2-25½"	
Stroke	18"	18"	15"	
Dia. of piston rods	3"	3"	2-3"	
Clearance in per cent	23	22	16	
Cylinder areas	153.94 □"	350.13 □"	1001.49 □"	
Net piston areas	150.40 □"	376.60 □"	994.42 □"	
Ratios of cylinder areas	1 : 6.506	1 : 2.635	1.000	
Ratios of net piston areas	1 : 6.612	1 : 2.641	1.000	
Ratios of cylinder volumes	1 : 6.236	1 : 2.511	1.000	
Revolutions per minute			357	
Steam at boilers	230 lbs. gauge		244.7 abs	
Steam at engine	210 " "		224.7 "	
Steam at 1st receiver	70 " "		84.7 "	
Steam at 2nd receiver	5 " "		19.7 "	
Vacuum			26 in's.	
Piston speed		1071 ft. per min.		
Mean effective pressure	109.5	41.3	14.63	
M.E.P. reduced to L.P.	16.56	15.65	14.63	46.84
Indicated horse power	535	505	472	1512
Per cent of total I.H.P.	35.38	33.40	31.22	100.00
Terminal of expansion curve			23.4 lbs. abs.	
Expansions		224.7 / 23.4	9.60	
M.E.P. from expansion curve to zeros			76.40	
M.E.P. actual from cards			46.84	
Card effect			61.3%	

Approximate steam consumption $\frac{1575 \times 0.625 \times 962}{46.84}$ = 16.45 lbs per H.P. hour

PLATE NO. 2.

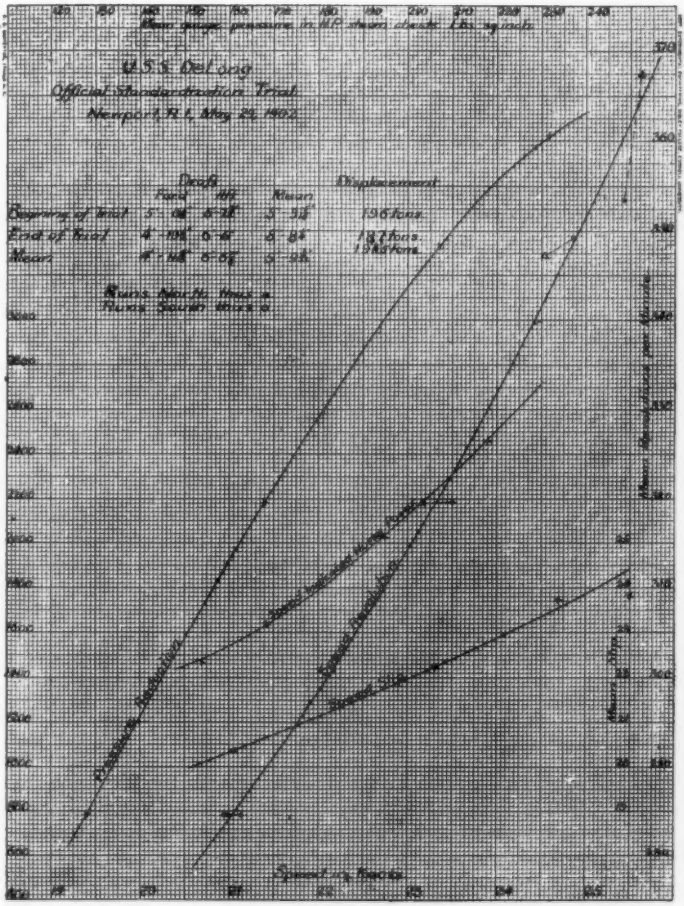


PLATE NO. 3

PLATE NO. 2.

SUBMARINE TORPEDO BOATS.

By Commander G. W. Baird, U. S. N., Member.

Among some unpublished manuscripts in my possession I have many of the notes of the late Engineer-in-Chief, W. W. W. Wood, of the Navy, as well as my own notes, sketches, etc., on the subject of torpedo boats, of both the surface and submarine classes.

When a Third Assistant on board the *Pensacola* during the Civil War, I had the pleasure of assisting Second Assistant Engineer Alfred Colin in the measurements and drawings of a submarine torpedo boat which had been fished out of the canal near the "New Basin," between New Orleans and the Lake Pontchartrain. Mr. Colin's drawing was sent by the Fleet Engineer (Mr. Shock) to the Navy Department.

The boat was built of iron cut from old boilers, and was designed and built by Mr. McClintock, in his machine shop in the City of New Orleans. She was thirty feet in length; the middle body was cylindrical, ten feet long, and the ends were conical. She had a little conning tower with a manhole in the top, and small, circular, glass windows in its sides. She was propelled by a screw, which was operated by one man. She had vanes, the functions of which were those of the pectoral fins of a fish. The torpedo, like that of Bushnell, was of the clock-work type, and, also like that of Bushnell, was intended to be screwed to the bottom of the enemy's ship. It was greatly superior to Bushnell's in that it was carried on top of the boat, and the screws employed were gimlet-pointed and tempered steel. Mr. McClintock (whom I met after the Civil War had ended) informed me that he made several descents in his boat, in the lake, and succeeded in destroying a small schooner and several rafts. He stated that the U. S. steamers *New London* and *Calhoun* had

been a menace on the lake, and this gave rise to the torpedo boat; but before an attack was made the fleet of Farragut had captured New Orleans, and his boat was sunk to prevent her falling into the hands of the enemy. His boat required but two men to operate it. He said they might have remained several hours under water without being seriously inconvenienced and without any extra storage of air. His ballast keel, which could be detached from the inside, was so weighted as to barely let the boat float with the conning tower awash. He frankly stated that the model of the boat was improper, in that the small dis-

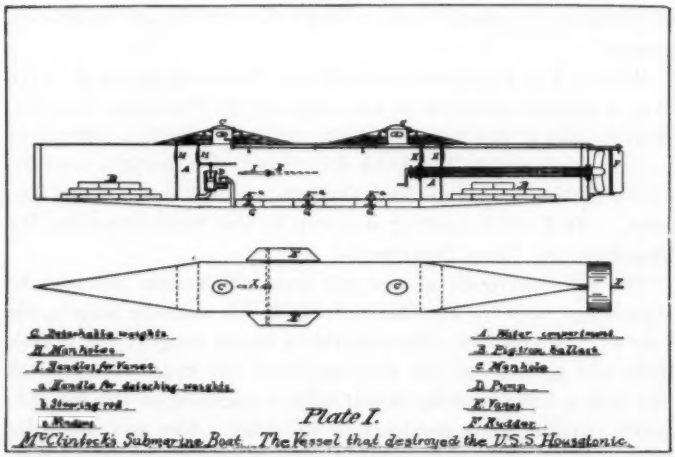


Plate I.

McClintock's Submarine Boat. The Vessel that destroyed the U.S.S. Housatonic.

placement afforded by the sharp ends was insufficient to keep the boat on even keel if a man moved a few inches forward or aft, and that this was a serious objection. After the capture of New Orleans Mr. McClintock went to Mobile, where he built the boat shown in Plate I. The boat was carried by rail to Charleston, and was successfully employed in the destruction of the U. S. steam sloop *Housatonic*. The torpedo boat, it will be seen, has a cylindrical middle body, but wedged-shaped ends. From the figures given me by Mr. McClintock I made, in his presence, sketches, from which I made the above drawing. The

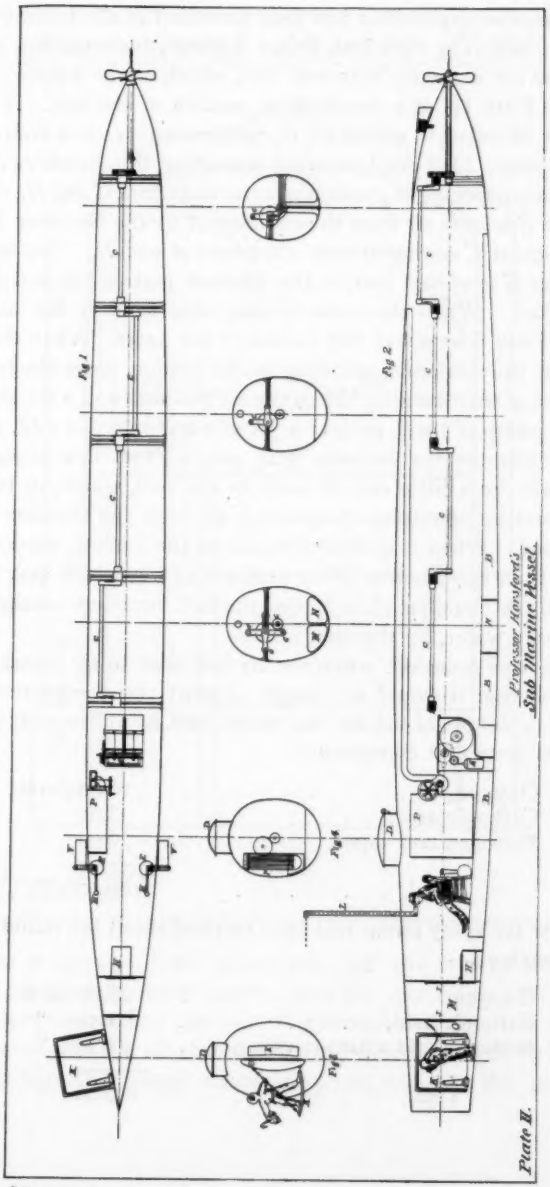
clock-work torpedo was abandoned with the New Orleans boat. The boat shown in the engraving used "a torpedo on a pole," as Mr. McClintock expressed it. The torpedo boat was not, apparently, injured by the explosion, but, for want of power, failed to regain the harbor, and, by a fresh wind, was blown out to sea and was lost. The boat was steered, as shown, by a rod which passed through a stuffing box in the stern. She had the "pectoral" vanes, and the detachable ballast of her predecessor, besides a bilge pump and watertight compartments. It was found that it was not necessary to secure the ballast carried inside the boat. He found, in practice, that he got better results by placing the "pectoral" vanes near the center of displacement; that his purpose was as well, and easier served, by sinking or rising bodily on an even keel as by diving. The utmost speed he could get with eight men was but three knots an hour; that the vitiated atmosphere rapidly diminished the men's strength; they complained more of being tired than from headache or nausea. That the boat was easily managed under water, and, when submerged 10 feet, she was not sensibly affected by the surface waves.

So far as the hydraulics of submarine-boat construction and the management of submarine flight are concerned, the experiments of McClintock in 1862–3 seem to have been conclusive. He had never heard of the boats nor the efforts of Bushnell nor of Robert Fulton. His inventions were as real as theirs, and, though not actually original, they were honest inventions. He belonged to that class of men who, in war and in peace, will ever be leaned upon in emergencies. The cause which led to Bushnell's inventions also led to his.

In 1863 our Government purchased from a Frenchman a torpedo boat which resembled Robert Fulton's *Nautilus*. It was essentially a navigable diving bell—a cigar-shaped vessel six feet diameter at the middle and about fifty feet in length, propelled by "duck-foot" paddles worked through holes in the sides (ball-and socket joints). She was built of iron. Like the *Nautilus*, she had a hole in her bottom amidship. She had airtight compartments, in which air at great pressure was

stored. The boat could not descend to great depths without injury to the crew. The hole in the bottom afforded an opening for the crew as well as the torpedo. In smooth water it is by no means a difficult feat for a good diver to enter or leave through such an opening. The Government paid $10,000 for the vessel, and substituted a screw propeller for the paddles, by which a marked increase of speed was obtained. An attempt to tow the boat to a southern port was then made, but she was lost off Hatteras. The contact of the air inside the boat with the water afforded a simple means of purifying the air, and though not entirely sufficient for that purpose, contributed much to it.

In 1864 Professor Horstford designed a large submarine boat which possessed good features. Plate II shows longitudinal section and plan, which need but little description. The professor estimated that his vessel could remain submerged for "several days" at a time. She was propelled by man power, through cranks and a screw propeller. The pectoral vanes were held in horizontal plane by pendulums, to insure horizontal flight. He employed water ballast for increasing or diminishing the weight of the vessel, using a pump to handle the water. He used, also, cast-iron internal ballast. Tubes having each two mirrors, as shown, which reached above the water, enabled the navigator to see above the surface. These tubes were intended to be telescopic, that they might be extended or shortened. By means of the pair of tubes and their angle when focused, the professor expected to determine distances. At *A* his anchor and windlass are shown. At *H* is the hydraulic port, and the diver about to place the torpedo. That which merits the most consideration is his method of purifying the air. A tank of oxygen gas, compressed to one-fifteenth its volume, was used. He employed a great surface of woolen cloth (*P*), which passed over pulleys and was dipped in lime water. A blower (*P*, Figs. 1, 2 and 4) kept the air moving over the wet surface. The lime water absorbs the carbonic acid gas. As this gas is absorbed and a small amount of oxygen liberated, the air may be kept nearly at normal purity. A common soda font (containing 45 cubic inches of oxygen at atmospheric pressure) will supply one man 81 hours.



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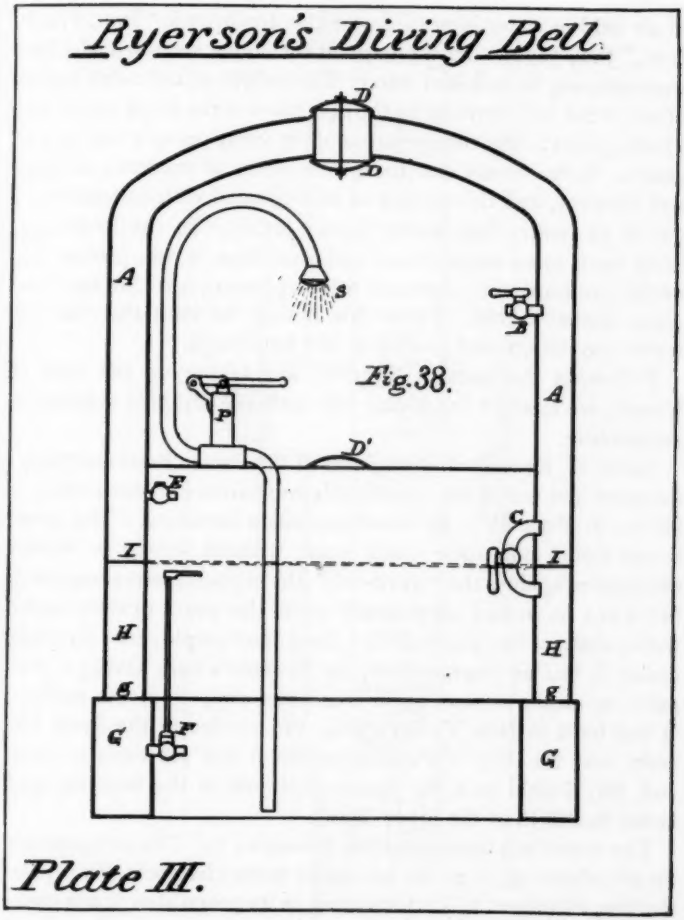
Submarine exploration has been practiced in all civilized parts of the world. In 1858 Van Buren Ryerson invented and put in practical use a greatly improved bell, which merits a place in this essay. Plate III is a longitudinal section of the bell. *A* is an airtight chamber in which air is compressed; *D* is a door, on a rubber joint; *I* is a diaphragm for separating the chambers *A* and *G*. A small opening at *g* communicates chambers *G* and *H*. A stop cock at *B* admits air from the chamber *A* to the chamber *S*. A stop cock at *C* communicates chambers *A* and *H*. The bottom chamber *G* is of cast iron, is the heaviest part of the bell and is for ballast. When the water is exhausted from *G* the dome of the bell will float above the surface of the water. When the bell is in use the workmen, standing on the bottom, move the bell by pressure of their hands. When the air becomes foul a few strokes of the pump (*P*) will project a jet of water into the bell, which readily absorbs the carbonic acid gas. From this absorption there will be a little rise of water in the bell, which, in turn, is depressed by admitting compressed air from the chamber *A*, as described. When it is desired to rise to the surface, water is expelled from the chamber *F* by pressure of air, which may be let in from the chamber *A*, and thus the bell becomes manageable, in smooth water, by the men inside.

Upon one occasion, when the air had been so far breathed by the men that it would no longer support the combustion of a candle, a sample of the air was taken, and, by subsequent analysis, 100 parts of it contained—

Oxygen,	16.00 parts.
Carbonic acid,	8.00 "
Nitrogen and vapor,	76.00 "
Total,	100.00 "

After the spray pump had been worked about ten minutes the air contained—

Oxygen,	26.00 parts.
Carbonic acid,	1.50 "
Nitrogen and aqueous vapor,	72.50 "
Total,	100.00 "



Thus it appears, from actual test, that the revived air contained 10 per cent. more oxygen than the impure air and about 5 per cent. more than the normal atmosphere. It must be remembered that the air absorbed by the water is a little richer in oxygen than the normal atmosphere, and also that the quantity

of air held in water increased with the depth (*vide* "Jour. Frank. Inst.," Jan., 1872). In the experiment above recorded, the bell was operating in 20 feet of water. The weight of 100 cubic inches of air in the bell previous to the operation of the spray pump was 33.060 grains; after the operation of the spray pump it was 31.025 grains. In the former case there were traces of ammonia, sulphur and chlorine, and the air was so impregnated with carbonic acid gas as to render lime water rapidly turbid. In the latter case there were more evidences of chlorine than in the former, but neither sulphur nor ammonia were apparent, nor did the lime water appear turbid. From this it may be seen that the sea water may be utilized greatly to our advantage.

Following the lines of Ryerson, and taking up the boat of Kroehl, we connect the diving bell with the dirigible submarine automobile.

Julius H. Kroehl, chief engineer of the Pacific Pearl Company, invented and put in use a navigable submarine explorer, which is shown in Plate IV. Its invention was a necessity. The pearl divers would not work under water without knives to defend themselves against the "devil-fish" (the cephaloptera-vampyrus), but when so armed they would open the pearl oysters under water, abstract the pearls and so cheat their employers. Kroehl's vessel is but an improvement on Ryerson's bell, having a propeller as means of moving in free water away from the bottom. It was built in New York in 1864, and carried to the Pearl Islands, near the Bay of Panama, where it was successfully used, and, Mr. Kroehl said, the divers employed in the boat enjoyed better health than the other divers.

The vessel had three principal divisions: (1) The compressed-air chambers (*A*); (2) the ballast or water chambers (*B*); 3 the working chambers (*C*). Excepting in its propulsion it was operated much the same as Ryerson's bell. The bottom of the boat could be opened or closed, as desired. When exploring in considerable depths the bottom was closed, to save the crew from the heavy pressure.

Mr. Kroehl, in 1861, designed a "cigar-shaped boat," but abandoned it for a flat-bottomed boat, as shown. His boat was

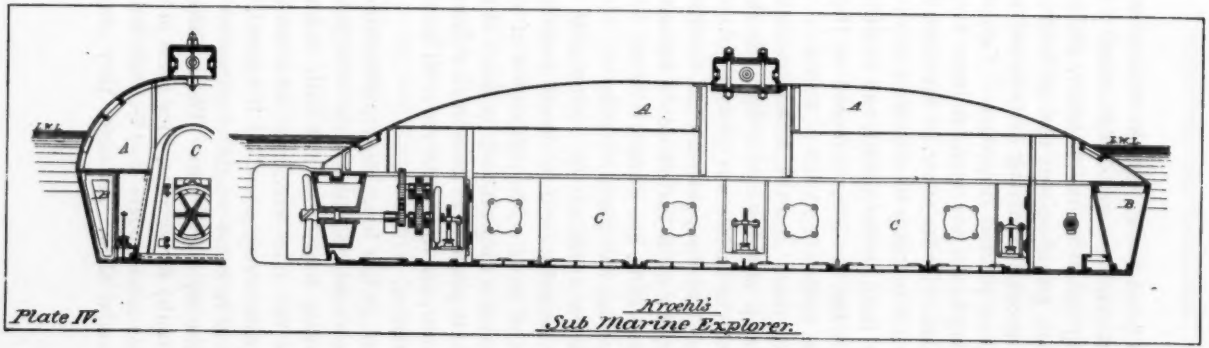


Plate IV.

Krochl's
Sub Marine Explorer.

36 feet long and 8 feet beam. At the center, between the compressed-air chambers, there was a distance of 7 feet 11½ inches. The screw was 3 feet 6 inches diameter, and was worked by hand. Mr. Kroehl was of opinion that his boat could have been used for war purposes, in entering harbors and severing electric wires which led to planted torpedoes. This would not be a very difficult thing to do, nor would it incur as great danger as might be supposed. Under water, in day time, it is easy to see anything *above*, but not easy to see below you. At night, with an incandescent lamp under a boat, one could see the bottom if very close to it, but the lamp, screened by the hull, could not be seen from the surface in 20 feet of water.

About twenty years ago the writer insulated a 16-candle-power electric lamp and lowered it into the clear water of the gulf stream when the surface was smooth. At a depth of 50 feet the last glimmer had disappeared. On the Bahama banks, in 25 feet of water, the white bottom could be barely seen when a lamp was lowered to it, but when a reflector was placed above the lamp the bottom was plainly visible.

All efforts to get speed out of a submarine boat have been futile; nor is it essential, for if the vessel become invisible there will be no need of haste. The application of an electric motor to the propulsion of a torpedo boat, by Scott Sims, about twenty years ago, made it possible to drive such a boat about eight or nine miles an hour, but the power required would soon exhaust any storage batteries.

However, enough has been already determined to assign the surface and the submerged boat each to its place in naval warfare. The surface boat, crammed with machinery, much of which is above the water line, with the water in its boilers so heated as to make every pound of it exceed, in potential, the explosive force of an equal weight of gunpowder, must face the deadly fire of the rapid-fire guns. To give the surface torpedo boats an opportunity for success, they must in day time hunt in droves, and their commanders may feel satisfied if one in twenty strikes a successful blow. At night they may go singly, but slowly.

The submarine boat is not quite out of the experimental state. A number of practical points, those not recorded in text books nor taught in school, must be ascertained by experiment. The more modern submarine boats are, in some respects, improvements on those referred to in this paper, yet such improvement is but in the details. The problem is tentative and purely mechanical, and needs now but practical tests to develop it. The writer became interested in the subject at an early age, and has always been of the opinion that the danger incurred in a surface boat is greater than in a submerged boat.

It may, however, be found, in actual practice, that the capabilities of both surface and submerged boats have been overestimated, but that both, doubtless, will be found to have their places in warfare. As a submarine explorer Kroehl's boat was a success. There is no difficulty in submarine wireless telegraphy, as every boy knows who has had his head under water when another boy was beating stones together; the impression upon the tympanum of the ear is acute and painful during such an operation. It only remains to improvise a code of signals in order to utilize this system and establish communication between a fleet and the bottom of a blockaded harbor.

It has long been known that the explosion of a torpedo upon the bottom will kill fishes in that vicinity, indeed this is now practiced by Canadian fishermen. It becomes at once of interest to know what would be the result of an explosion near a submarine boat, and the best methods and best form of boat to resist such a contingency. There are other practical questions which need to be determined, but it is needless to multiply them here. Such a boat as McClintock or Kroehl produced, propelled by an electric motor and storage battery, would answer for all experimental purposes, and not be very expensive. A generating set in the boat would add greatly to its complication, and, in the opinion of the writer, would rather detract from than add to her efficiency.

THE CONTRACT SPEED TRIAL OF THE U. S. TORPEDO BOAT *WILKES*.

By Lieutenant Albert Moritz, U. S. Navy, Member.

The *Wilkes* is a torpedo boat for the United States Navy, constructed by the Gas Engine and Power Co. and Chas. L. Seabury & Co., consolidated, Morris Heights, New York City. She was designed for 165 tons trial displacement, but the actual displacement on the official trial of June 6, 1902, was 204.75 tons. The actual displacement under service conditions will be 260.79 tons.

The contract for this boat was signed September 30, 1898; $146,000 was named as the cost, on a guarantee that she would develop on her speed trial 26½ knots an hour for two consecutive hours.

The speed requirement was subsequently modified, by order of the Navy Department in letter to the Bureaus of Steam Engineering and Construction and Repair, dated February 26, 1902, to an average speed of at least 24 knots for one hour.

The modification was a result of a request by a Committee of the Contractors for the Construction of the Torpedo Boats and Torpedo-Boat Destroyers authorized by the Act of May 4, 1898, on account of extraordinary expenses incurred by them in the fulfillment of said contracts and their desire to keep down expenses. In the opinion of the writer, the modification of the speed requirements lessened the expense of the contractors materially, viz: the cost of numerous preliminary trials to "tune up." However, it is his belief that the *Wilkes*, at 165 tons displacement and with clean bottom, could make 26½ knots.

The same high requirements as to the machinery, the material, the stability and the maneuvering and sea-going qualities were demanded as for all U. S. naval vessels. As a matter of fact, the materials used and the workmanship applied in the construction of the *Wilkes* were of the very best quality.

The time allowed for completion—one year—was extended by approval of the Navy Department, on account of labor troubles at the contractors' works and the difficulty in getting material.

Some delay occurred, also, on account of spongy material and cracks discovered in the main-cylinder castings after they were nearly machined. In fact, one high and intermediate-cylinder casting (both in one casting) was entirely finished, and only failed on the pressure test.

THE HULL.

The hull is constructed of steel of domestic manufacture. It is provided with two conning towers, cabin, wardroom, storerooms, pantries, staterooms, magazine, waterclosets, complete steering and drainage apparatus and wooden signal pole. It also has an electric plant for lighting the vessel, and one search light. The wood used was treated by a fireproofing process.

The first of the flat keel plates, 10 pounds per square foot, was laid June 3, 1899, nearly nine months after signing of contract, due to difficulty in getting material. The vertical keel plates are 15 pounds per square foot, and eight inches in depth generally. There are 115 transverse frames and deck beams, which are spaced 18 inches from center to center.

Nearly the whole of the outside plating (from 18 inches above designed water line to keel), floor plates, bulkhead plates, reverse frames and frames were galvanized by the hot process.

The vessel is divided into eleven watertight compartments, viz: two engine rooms and two fire rooms, including coal bunkers; two crew spaces, including galley and stores; one cabin, including officers' quarters, pantry and stores; one magazine, one fore peak, one windlass compartment, and one tiller compartment.

The doors and manholes and stuffing boxes in bulkheads are made watertight.

The forward conning tower is formed of nickel-steel plates, 20 pounds per square foot.

A feature of the officers' and crew spaces is that the overhead work consists of very light fireproof wood frames, covered with sheet zinc 5 ounces to the square foot, in order to leave an air space immediately beneath the deck plating. This feature has

been carried out on other vessels in another way, viz: by painted canvas. It has been found by actual experiment at the works of the Gas Engine and Power Company that the painted canvas weighs more than the zinc sheets.

THE BATTERY.

The battery consists of three 1-pounder Hotchkiss rapid-fire guns, heavy, Mark II, mounted on Cage stands, Mark III; three center-pivot torpedo tubes for 3.55-millimeter torpedoes.

In connection with the torpedoes there is a Rand air compressor, Type 4, with a separator and strainer at each torpedo tube. Piping connects the torpedo tubes with the air compressor. The air compressor is installed on the starboard side, forward, in the after engine room.

The location of the gun mounts is as follows: Two 1-pounders on each beam just abaft the forward conning tower; one 1-pounder amidships, abaft the after conning tower; two center-pivot torpedo tubes, located singly, just forward of the midship section of the vessel, one on the starboard and one on the port beam; one center-pivot torpedo tube amidships, immediately over the after watertight bulkhead.

The steam line for the air compressor is fitted with a reducing valve so as to use steam at 80 pounds pressure.

THE PROPELLING ENGINES.

The propelling engines—two sets—are of the vertical, inverted-cylinder, direct-acting, triple-expansion type, each with one high, one intermediate and two low-pressure cylinders, and designed for about 3,000 H.P. when the engines make 350 revolutions. The starboard engine is placed forward and the port engine aft, and are supported by vertical forged-steel columns; the bed-plates are of cast steel; crank shafts of nickel-steel, hollow and in two sections; the shafts, the piston rods, connecting rods, the eccentric rods and working parts in general are forged of nickel-steel.

Each has four cylinders—the high-pressure forward, followed by the intermediate-pressure, the first low-pressure and the sec-

ond low-pressure—diameters, 14 inches, 22 inches, 25¼ inches and 25¼ inches, respectively; stroke, 18 inches; one piston rod for each cylinder, diameter, 3 inches. Each cylinder has one piston valve.

A novel method of bracing high-power marine engines is applied on the *Wilkes*. In addition to the bracing of the engines themselves the entire engines are braced to the deck beams of the hull. The bracing takes hold of stout nipples in the middle of the cylinder covers, and are made with turn-buckles for easy adjustment and to facilitate the removal of cylinder covers.

Two stout braces extend from the forward side of each thrust bearing to the engine bedplate itself, to assist in stopping fore-and-aft vibrations. Where lightness of construction is a necessity this is an excellent idea.

The valve gear is of the Stephenson type with double-bar links; the cut-off is regulated by screw adjustments at the end of the reverse arm of each cylinder. The engines may be reversed by steam or by hand.

The condensers are cylindrical, of Muntz metal; steam on outside of tubes and each having a total cooling surface of 2,481.4 square feet.

The air pumps are of the Bailey type, driven by the second low-pressure crossheads, differing in this respect from those of other torpedo boats of the same class, which are driven from the main-engine shafts.

There are three Seabury water-tube boilers, 10 feet 10 inches wide, 7 feet 11¾ inches long; two furnaces in each boiler, total grate surface, 137.4 square feet; heating surface, in each boiler, 2,600 square feet.

The fire rooms are arranged to be closed for forced draft. There is one vertical centrifugal blower for each boiler. Other torpedo boats of the same class as the *Wilkes* are arranged with horizontal blowers. The blowers and blower engines were made by the contractors.

There are three oval smoke pipes, 5.64 square feet area. The heights of the tops of the smoke pipes above the grates are, for

boiler, A, 20 feet 1¼ inches; for boiler B, 20 feet 6 inches, and for boiler C, 18 feet 4 inches.

There are two true-pitch propellers, built solid, inclined aft, each with three blades of manganese-bronze; pitch, 8 feet 8 inches; diameter, 5 feet 6 inches; total helicoidal area of each propeller, 10.41 square feet.

The vessel is provided with the following pumps of the Davidson pattern:

One auxiliary feed pump in the starboard engine room, which may be used as fire and bilge pump, for ash ejectors, and for furnace fire extinguishers.

One main feed and one fire and bilge pump in the port engine room. The fire and bilge pump may be used for ash ejectors and for furnace fire extinguishers.

One main feed pump in the forward fire room.

One distiller circulating pump and one evaporator pump in the after fire room. The distiller circulating pump may be used for water service on main engines.

There are two ash ejectors, one in each fire room.

There are two evaporators and one distiller in after fire room with a maximum distilling capacity of 1,700 gallons per day, and an ordinary distilling capacity of 1,000 gallons per day.

There are eight coal bunkers, having a capacity of about 65 tons of coal.

The engine rooms are lighted by eight fixed steam-tight globe lamps of 16-candlepower each, and the fire rooms by seven of the same kind. Besides there are six portable lamps of 16-candlepower each, for general use in the department.

The dynamo is of the General Electric Company's marine type, multipolar, compound, and is designed for 80 volts and 2½ kilowatts; is run by a Seabury engine designed for 800 revolutions. The engine is of the vertical, inverted-cylinder type; diameter cylinder, 4 inches; stroke, 4 inches; piston valve, dynamo and engine direct-coupled on one bedplate and provided with a flywheel governor.

There is a Hyde cable windlass with gypsy head, operated by

double horizontal engines. Diameters of cylinders, 3¼ inches; stroke, 4 inches.

There is also a steam steering engine, made by the Hyde Windlass Company, horizontal, double-cylinder type; diameters cylinders, 3½ inches; stroke, 3½ inches.

In addition the boat is provided with steam radiators and a Rand air compressor for charging and operating the torpedoes and torpedo tubes.

The only steam traps provided are for the heating system. They are of the Kieley's cantilever expansion type. The design appears to be particularly well adapted for use on torpedo boats, as excessive vibration has little or no effect in operating the valves.

Following is a recapitulation of weights of machinery:

Propelling machinery, tons,	78.17
Water in above machinery (boilers 4 inches above highest heating surface), tons,	9.93
Stores, tools, instruments and duplicate pieces, tons,	4.80
Miscellaneous machinery under Bureau of Steam Engineering, tons,	2.26
Total weight at time of completion of machinery, tons,	95.16

The weights were made up for the official trial as follows:

Propelling machinery, including necessary water, stores, tools and miscellaneous machinery in department of steam engineering, tons,	91.6
Hull and fittings, tons,	77.24
Coal, ordnance, equipment and crew, tons,	35.91
Total trial load, tons,	204.75

Further details of the machinery of this vessel are almost identical with the boats of her class, the *Shubrick* and the *Thornton*, previously described in this JOURNAL, and, in consequence, are not repeated in this report.

THE TRIAL.

The *Wilkes* left Morris Heights, New York city, 5·15 A. M., June 2, 1902, for Newport, R. I., arriving there on the same day about 1·30 P. M.

The crew on this run and on the subsequent trial runs was made up almost entirely of the leading men and men from the contractors' shops. Mr. Chas. L. Seabury, vice-president of the contracting firm, had immediate charge of the trials for the contractors.

The crew consisted of the following men:

For the engineers' force: One master mechanic in charge, two licensed chief engineers (marine), one draughtsman (recorder), one machinist, one coppersmith, one ironworker, four oilers, two blower men (one engineer and one machinist), three water tenders, six firemen, two foremen for fire rooms (one superintending boiler maker and one leading man), two coal passers.

The crew on deck consisted of one captain, one mate, five deck hands, two cooks and one messman.

With the exception of one engineer, no one of the trial crew had been on the preliminary trials of the boat more than five times, but most of them had had experience on the trial of the U. S. torpedo boat *Bailey*,

On June 5, 1902, the *Wilkes* successfully completed the standardization trials on the measured trial course at Newport. The trials commenced at 12·15 P. M., and were completed at 1·40 P. M. The trials were conducted by the Naval Board of Inspection and Survey, composed of Captains W. W. Mead and Chas. R. Roelker, Naval Constructor J. J. Woodward, Commander Chas. E. Vreeland and Lieutenant Commander T. S. Rodgers. Captain Roelker was the engineer expert of the Board, and was assisted in taking engine data, etc., by Lieutenants G. S. Lincoln and R. I. Curtin, U. S. N.

No indicator diagrams were taken during the trial, but cards were taken on several of the preliminary trials.

The conditions of wind and sea were favorable, and the several double runs were made at the rates prescribed by the precept for the trial. The beginning and the end of the measured mile were marked by an observer, one of the Naval Board.

STANDARDIZATION TRIAL DATA OF U. S. T. B. *WILKES*, JUNE 5, 1902.

	1st double run		2d double run.		3d double run.		4th double run.	
Direction	N.	S.	N.	S.	N.	S.	N.	S.
Duration, minutes and seconds	3-02.5	2-50.8	2-43.0	2-37.8	2-30.8	2-27.1	2-19.2	2-17.8
Speed, knots	19.726	21.077	22.086	23 814	23.873	24.473	25.862	26.125
Mean speed for double run, knots	20 4015		22.450		24 173		25.9935	
Total revolutions each run, starboard,	909	871	905	884	911	888	905	903
port	896	863	901	878	906	880	904	904
Mean revolutions per minute	300.6		333.675		361		391 6	
slip of screws, per cent	20.65		21 34		21.71		22.4	
Steam pressure above atmosphere :								
Steam pipe in e. r., lbs., starboard	138	146	182	189	216	220	243	253
port	138	138	186	189	223	217	245	252
I.P. receiver, pounds, starboard	47	53	68	70	82	86	92	95
port	44	44	63	67	79	78	91	94
L.P. receiver, pounds, starboard	2	2	3	3	2 3	2.3	3	2
port	3.6	4	9.3	9.7	13	12.5	15.3	15.6
Vacuum, pounds, starboard	24.7	24.9	23.4	23.7	22 8	22 6	22	21.9
port	22.3	22 7	20.6	20.2	19	18.6	21	20.1
Air pressure, forward fire room, lbs	1.8	5.5	3.7	2.1	3.4	4.3	4	6
after fire room, pounds	.2	.6	1.4	1	3.3	2.8	3 6	3.7

Displacement at commencement of the standardization runs, 209 tons.
Displacement at end of the fourth double run, 204 tons.

FULL-POWER CONTRACT SPEED TRIAL U S. T. B. *WILKES*, JUNE 6, 1902.

Time, P. M.	Revolutions of counter.	Revolutions per minute.	Steam pressure above atmosphere. Steam pipe E. R.	First receiver.	Second receiver.	Vacuum.	Injection.	Discharge.	Feed.	Air pressure, F. R.
			Starboard Engine.							
4'22	16,700	.....	240	90	.....	23	59	.....	94	6
4'32	20,496	379.6	240	87	.....	22.7	57	.....	84	6
4'42	24,253	375.7	229	80	.....	23.5	57	.....	85	5
4'52	27,951	369.8	240	87	.....	23	56	.....	84	4.5
5'02	31,677	372.6	242	88	.....	22.9	57	.....	84	3.5
5'12	35,409	373.2	256	86	.....	23.4	56	.....	83	4.2
5'22	39.151	374.2	245	90	.....	22.8	59	.....	84	3.75
Mean.....	$\frac{22,451}{60}$ =	374.18	241.7	86.9	.....	23.04	57.3	.....	85.4	4.71
			Port Engine.							
4'22	.....	.....	245	88	14	20	56	62	78	4.5
4'32	3,760	376	240	87	14	20.5	55	62	80	3.5
4'42	7,525	376.5	232	85	14	19	55	60	75	3.9
4'52	11,255	373	235	85	13	18	55	60	75	4.1
5'02	15,005	375	245	88	14	18	55	60	75	3 8
5'12	18,720	371.5	237	86	13	18	55	60	75	4.7
5'22	22,465	374 5	240	91	14	18	55	60	75	4.2
Mean.....	$\frac{22,465}{60}$ =	374.42	239.1	87.1	13.7	18.8	55.1	60.6	76.1	4.1

Mean revolutions of both engines, $\left(\frac{374.18 + 374.42}{2}\right) = 374.3$.
Corresponding speed of vessel = 24.97 knots.
Mean displacement during the one-hour's run, 204.75 tons.

HULL DATA CORRESPONDING TO OFFICIAL TRIAL CONDITIONS, JUNE 6, 1902.

Length between perpendiculars, feet	175
on L.W.L., feet	175
over all, feet	175
Beam, extreme, feet and inches	17–7⅛
at midship section on L.W.L., feet and inches	17–1⅞
Ratio of length to beam	10.37 to 1
Depth at side (midship section) to top of floor, feet and inches	11–2
Mean draught, trial by draught marks, feet and inches	6–0$\frac{23}{32}$
Corresponding displacement, tons	204.75
Tons, per inch at trial draught	5.45
Area immersed midship section, square feet	69.37
Center of gravity, L.W.L. aft of midship section, feet	2.25
Center of buoyancy above bottom keel, feet	3.31
Center of buoyancy forward of midship section, feet	6.55
Transverse metacenter above center of buoyancy, feet	6.2
Longitudinal metacenter above center of buoyancy, feet	568.

SOME TRIAL OBSERVATIONS.

The steam gauges in engine and fire rooms were tested before and after the trials, and the data given represents the corrected readings in accordance with these tests.

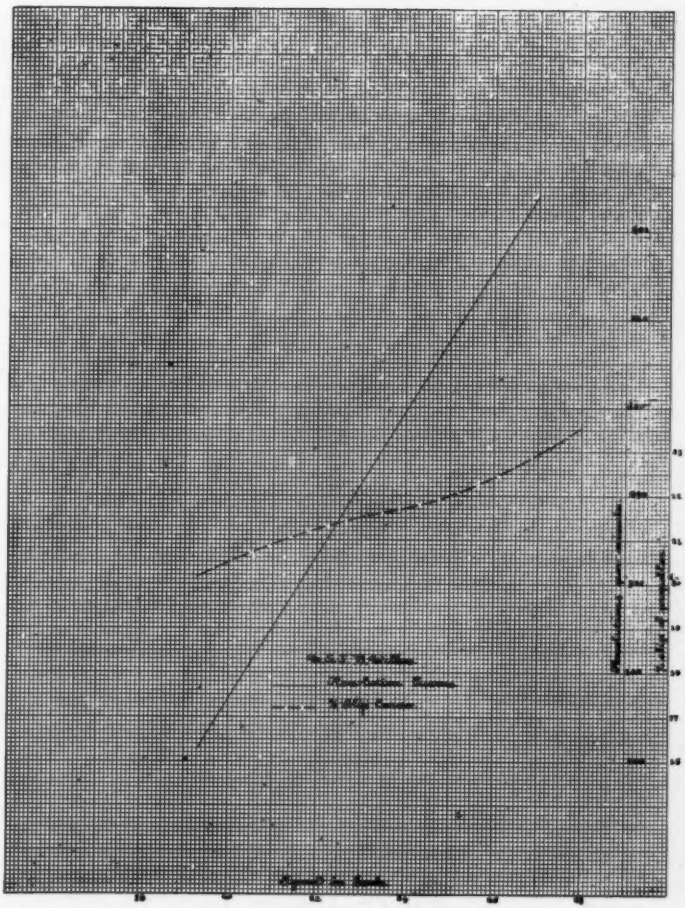
The safety valves were set to blow off at 265 pounds above the atmosphere, but were observed to lift at about 260 pounds during the trials, which is 6 per cent. above the contract working pressure.

The revolution counters of the engines were installed on deck, operated by worm gear from the main shafts. They were provided with clutch couplings to throw them in or out of gear.

The fuel used during the trial was picked Pocahontas coal, of good quality. No record was kept of the amount consumed.

The machinery, both main and auxiliary, worked very satisfactorily during all the runs. The throttles of both engines were fully opened during the standardization runs as well as during the full-power speed trial. The vibration of the engines and pipes was very slight. Water was used on some of the bearings and eccentrics as a precautionary measure.

The air pumps worked excellently without causing any anxiety whatever. Undoubtedly the method of applying the power in working these pumps, together with their firm foundations, made this possible.



The fire-room blowers and engines, built by the Gas Engine and Power Co., were extremely steady and free from vibrations at speeds ranging from 1,000 to 1,300 revolutions, and while maintaining an air pressure in the fire rooms of about six inches.

The vessel had started to run her one-hour's full-speed trial at 9·05 A. M., June 6, 1902, but after running ten minutes a nipple on the cylinder head of the first low-pressure cylinder of the port engine, to which the relief valve is secured, broke flush off with the cylinder cover. The breaking of the nipple was caused by setting up too hard on the brace which ties the top of the cylinder to the deck beams. The accident made it necessary to postpone the trial until later in the day. The broken nipple was replaced, and the one-hour's full-speed trial was resumed at 4·22 P. M., of June 6, 1902, and lasted exactly one hour. The mean displacement during this run was 204.75 tons.

The diagonal brace on the back of the port engine was broken during the final trial at the thread of the lower end, just outside of the lug on the bedplate. A similar break occurred during one of the contractors' preliminary trials.

"Reflex water gauges" (Klinger's patent) were used on the boilers during the trials. They proved extremely satisfactory. The height of the water could be readily seen from any part of the fire rooms. They have great strength and are excellent for quick action.

The trial displacement was 39¾ tons more than the designed trial displacement. This added 7.2 inches draught over the draught corresponding to the designed displacement. Bearing this in mind, and that the vessel had been out of dock since April 17, 1902, a period of nearly two months, it can be readily seen that the speed developed on the one-hour's run, 24.97 knots, could have been easily exceeded under more favorable conditions.

The contractors did not do their utmost to get the best speed, but were satisfied with a fair margin over that required.

In conclusion, I have to thank Mr. Chas. L. Seabury and his assistants, of the Gas Engine and Power Co., for valuable assistance furnished.

REPORT OF THE BRITISH ADMIRALTY COMMITTEE ON NAVAL BOILERS.

1. The Committee desire now to approach their Lordships with a Report, intended to be as nearly final as the circumstances of the case will permit, in regard to some of the questions raised in the Letter of Reference, dated September 6, 1900, and their Lordships' letter of February 28, 1901; although, for reasons which are afterward stated, they are not in a position to "authoritatively recommend a standard boiler for the use of H. M. Navy," as requested in the letter of February 28, 1901.

2. The work done by the Committee has been as follows:

The investigation of the behavior of water-tube boilers in British and foreign navies and in mercantile vessels, by visiting many ships in these services, and by obtaining evidence from Admiralty and Dockyard officers; from a representative of the Board of Trade; from superintending engineers who have had experience with the design and upkeep of such boilers; from makers of these boilers and from officers entrusted with the care of them.

The supervision of trials in H. M. ships *Europa*, *Diadem* and *Minerva*, the Cunard S. S. *Saxonia*, H. M. ships *Hyacinth*, *Sheldrake*, *Espiègle*, *Fantôme* and *Seagull*.

The consideration of a large number of different types of water-tube boilers; and in cases where water-tube boilers of types intended for use on shipboard have been under steam on shore, inspections of them have been made, and their behavior inquired into.

The examination of the engine-room registers of fifteen of His Majesty's ships fitted with Belleville boilers and eleven fitted with cylindrical boilers, for the period January 1, 1901, to September 30, 1901, in order to ascertain the relative economy and efficiency of these boilers on active service.

They have arranged for the reboilering and the necessary machinery alterations of the *Medea* and the *Medusa*, for the purpose of obtaining experience with two types of boilers, the Yarrow large-tube and the Dürr, which had not been previously fitted in H. M. Navy.

Further, such questions as have been put to them by their Lordships from time to time have been answered.

3. The records of their inspections of the evidence, and of the results of the trials, together with the deductions from them, have been forwarded for their Lordships' information in the following documents:

The Interim Report, forwarded February 19, 1901.

The Minutes of the Evidence given before the Committee, together with the Appendix thereto, forwarded April 26, 1901.

The report on the trials of *Hyacinth*, *Minerva* and *Saxonia*, together with the summary of conclusions, forwarded November 27, 1901.

The Progress Report for the year 1901, forwarded December 31, 1901.

The report on the relative economy and efficiency of Belleville and cylindrical boilers in commissioned ships, forwarded April 29, 1902.

4. It was desired that the Committee should investigate and report as set forth in Paragraph 3 of the Letter of Reference. In section (*a*) of that paragraph, the Committee were requested to "ascertain practically and experimentally the relative advantages and disadvantages of the Belleville boiler for naval purposes, as compared with the cylindrical." In order to comply with this request, the Committee have examined the boilers of many of His Majesty's ships, inspected many boiler tubes removed from ships at the home dockyards, received evidence from engineer officers, and considered the defect lists received from ships. An exhaustive series of trials between the *Hyacinth* with Belleville boilers, and the *Minerva* with cylindrical boilers, and a full-power trial under service conditions, and of 24 hours' duration, in H. M. S. *Diadem*, have been carried out under their direction.

5. Experience thus obtained has confirmed the Committee in the opinions expressed in their interim report, viz: "that the advantages of water-tube boilers for naval purposes are so great, chiefly from a military point of view, that, providing a satisfactory type of water-tube boiler be adopted, it would be more suitable for use in H. M. Navy than the cylindrical type of boiler;" further, that the "Belleville boiler has no such advantages over other types of water-tube boilers as to lead them to recommend it as the best type to be adopted by H. M. Navy."

6. Since forwarding that report the Committee have continued their investigations with regard to the Belleville type of boiler, among others, and they have seen no reason to alter what they then said concerning it. They have also carefully considered the remarks made by Messrs. Delaunay-Belleville & Co. upon the Interim Report and upon the report on the trials of the *Hyacinth*, *Minerva* and *Saxonia*, but they found nothing in them which alters, in the least, their opinion upon the subject. In these remarks the bursting of a tube in one of the *Hyacinth's* boilers, a serious accident, in the Committee's opinion due to defective circulation, is only mentioned as an occurrence of no importance. The Committee fully recognize that the Belleville boiler, when new and in good condition, is a good steam generator, but its rapid loss of efficiency in ordinary work in commissioned ships, the serious character of the defects which have been developed in it, and the great care required in its manipulation render it, in the opinion of the Committee, undesirable to fit any more of this type in H. M. Navy.

7. Since the reports on the visits of the Committee to Paris and Marseilles the use of lime and zinc has checked the rapid deterioration of the boiler tubes experienced in the earlier vessels fitted with Belleville boilers. The Committee regret to find, on the other hand, that serious defects in the boiler casings have made their appearance in several cases, and have rendered the vessels in which they have occurred unserviceable for long periods.

8. The disadvantages of the Belleville boiler, as compared with the cylindrical boiler, are as follows:

(*a*) The circulation of water is defective and uncertain and the water gauges do not indicate the amount of water in the boiler. These causes have led to serious accidents.

(*b*) An automatic feeding apparatus of a delicate and complicated kind is necessary, in order to make the safe working of the boiler possible.

(*c*) A great excess of pressure over that in the boiler is required in the feed pipes and pumps.

(*d*) A considerable excess of boiler pressure over the working pressure at the engines is necessary.

(*e*) The quantity of water varies at different rates of combustion, although the same level may be shown on the water gauges.

(*f*) Separators with automatic blow-out valves on the main steam pipes are required in order to provide for water thrown out of the boilers when the rate of combustion or the speed of the engines is suddenly increased.

(*g*) A constant and excessive loss of feed water.

(*h*) The upper generator tubes are liable to fail by pitting or corrosion, and, in economizer boilers, the economizer tubes are still more liable to fail from the same cause. The trouble from this cause has diminished recently, but the liability of these parts to corrosion still exists, and must be regarded as a serious disadvantage.

(*i*) The upkeep of Belleville boilers has proved to be exceedingly costly, whereas that of cylindrical boilers is trifling, and this disproportion is likely to increase materially with the age of the boilers. On account of the necessity for more repairs, ships with Belleville boilers will be laid up more frequently and for much longer periods than similar ships with cylindrical boilers.

(*k*) The additional evaporating plant required with Belleville boilers, and their greater coal consumption on ordinary service as compared with cylindrical boilers, has hitherto nullified, to a great extent, the saving of weight effected by their adoption, and in considering the radius of action of ships fitted with them no real advantage has been gained by their use. The Committee cannot say, however, whether this may not apply to other types

of water-tube boilers. This can only be determined by extended experience.

9. As compared with the cylindrical boiler, a satisfactory water-tube boiler should possess the following advantages:

(*a*) Less delay in steam raising.

(*b*) Less liability to damage if the boiler be struck by a projectile.

(*c*) Greater ease of repair and renewal of parts.

(*d*) Less weight for the power generated, considering the weight of the boiler installation only.

(*e*) Ability to carry a higher steam pressure.

(*f*) Greater fire-grate area for the same floor area, with consequent less forcing for full power.

To a considerable extent these advantages are possessed by the Belleville boiler, but the Committee consider that they are more than counterbalanced by the disadvantages enumerated in Paragraph 8.

10. From the report on the trials of the *Hyacinth* and *Minerva*, it will be seen that, during the Channel trials, the Belleville boilers of the former were more efficient, as regards evaporation, than the cylindrical boilers of the latter as originally fitted; but that, after retarders were fitted in the boiler tubes of the *Minerva*, the efficiencies were nearly equal. The long runs to Gibraltar and back showed that, in several respects, notably in smallness of feed water and in economy of coal consumption, as well as in the immunity from accident during ordinary working, the cylindrical boilers were considerably superior to the Belleville.

11. In reference to the first part of Section (b) of Paragraph 3, of the Letter of Reference, the Committee are asked "to investigate the causes of the defects which have occurred in these [Belleville] boilers, and in the machinery of ships fitted with them, and to report how far they are preventable, either by modifications of details or by difference of treatment, and how far they are inherent in the system." In reference to this matter, the Committee have visited many of H. M. ships fitted with Belleville boilers, including the *Powerful*, *Ariadne*, *Europa*, *Hermes*, *Furious*, *Arrogant*, *Niobe*, *Diadem*, *Hyacinth*, *Vestal* and

Good Hope, and have seen the lists of defects reported from the Channel Squadron, Mediterranean Fleet and the China Station. From the knowledge thus obtained, the Committee are of opinion that, as stated in the Interim Report, "to obtain satisfactory results in working the boilers in face of the disadvantages named * * * more than ordinary experience and skill are required on the part of the working staff."

12. The principal defects which have arisen in the ordinary working of Belleville boilers on board H. M. ships are:

(*a*) Corrosive decay of the baffles in the steam collectors, and of generator and economizer tubes. This has been caused by the intermittent character of the circulation of the water in the boiler, by which surfaces exposed to heat are alternately wetted and dried, and by the presence of air in the feed water, which experience has shown to be particularly injurious to feed-water heaters placed in the uptakes of marine boilers; also, until recently, for want of the proper preservative treatment. The rate of decay has now been reduced by the use of lime and zinc, but great care has to be taken in order to prevent choking of the water-gauge connections, in consequence of this necessary free use of lime. Belleville boilers, having undrowned generator tubes and a very large amount of feed-water heater surface in the uptakes, are more liable to injury by corrosion than any of the four types of water-tube boilers which are named by the Committee as suitable for trial.

(*b*) The rapid wear of the working parts of the automatic feed apparatus and of the non-return valves in the down-take pipes.

(*c*) The burning and warping of the uptakes, boiler casings and boiler supports, with consequent falling off in efficiency owing to the leakage of air into the uptakes. Serious injury to the boilers has, in some instances, resulted from this cause.

The burning of boiler casings and supports can be reduced to a minimum by special design and to some extent by skillful stoking of the fires, but it is probable that this will be a more or less serious working defect in this and other types of marine water-tube boilers.

(*d*) The melting of fusible plugs, owing to the defective and

uncertain character of the circulation of the water. This defect has been a very general source of trouble, but, as these plugs are necessary for the safe working of the boilers, their melting in particular elements cannot be avoided when the rate of combustion under them is varied to any considerable extent.

(*e*) The deposit in the tubes about the water line, especially in the wing elements. This occurs when the feed water is not pure and a sufficiently active circulation is not being maintained. This serious defect has been the cause of tubes failing in several instances.

(*f*) Leaky nipple joints. These have given great trouble.

(*g*) The decay and fracture of the pipes connecting the float chambers and the water-gauge fittings to the elements. This has been mainly due to the use of unsuitable material.

(*h*) The excessive expenditure of coal and of fresh water for boiler-feed make-up, as compared with similar vessels fitted with cylindrical boilers. The expenditure of coal in ships fitted with Belleville boilers has been very high, both for auxiliary purposes in harbor and for propelling purposes. The loss of water has, up to the present, been an unsatisfactory feature in the working of Belleville boilers, notwithstanding all the care which has been taken to guard against it.

Of the above defects, *a*, *b*, *d* and *e* are inherent in the Belleville system. With reference to *h*, it is considered that the loss of water is also inherent in the system.

13. With reference to the latter part of section (b) of Paragraph 3 the Letter of Reference, where the Committee are requested "to report generally on the suitability of the propelling and auxiliary machinery fitted in recent war vessels, and offer any suggestions for improvement, the effect as regards weight and space of any alterations proposed being also stated," the Committee consider that the propelling and auxiliary machinery as fitted in recent war vessels are generally suitable, and the suggestions they desire to make on this matter are set forth in the following paragraphs:

(*a*) *Length of Stroke and Number of Revolutions.*—They consider it desirable, where practicable, to increase the length of

stroke and reduce the number of revolutions per minute, as compared with the recent practice in H. M. service. This was referred to in Section 11 of the "Summary and Conclusions drawn from the Report on the trials carried out in the *Hyacinth* and *Minerva*," where the Committee called attention to the advantages of the longer stroke and of reducing the number of revolutions.

(*b*) *Condensers.*—Where two main condensers are fitted to each set of main engines the Committee consider that auxiliary condensers need not be fitted, if the auxiliary engines are arranged to exhaust into either part of the main condensers.

(*c*) *Jackets.*—With the piston speeds now adopted jacketing is regarded as of doubtful advantage, even at comparatively low powers. It is considered that all jacket steam and drain connections on the H.P. and I.P. cylinders may be omitted without loss of economy. They should be retained on the L.P. cylinders, but only in the machinery of second-class cruisers and larger vessels.

(*d*) *Air Pumps.*—It is recommended that independent steam-driven air pumps should be adopted where practicable, for the following reasons:

(1) The main engines would be relieved of reciprocating parts, which require much attention when running at high speed; there is also a risk of excessive loads coming on the pumps, due to irregularity in the supply of water in consequence of the rolling and pitching of the ship.

(2) The work can, at all powers, be adjusted to the air leakage with resulting economy.

(3) The vacuum can be maintained and the condensers kept thoroughly drained while the main engines are not at work, thus making it more easy to handle the engines.

(4) Hotwell pumps may be abolished.

(5) With slow-running pumps the water can be delivered into the hotwell tanks more free from air than in the case of pumps driven off the main engines.

(6) Auxiliary air pumps may be dispensed with.

In cruiser engines of 22,000 indicated horsepower, if the auxiliary condensers with their air and circulating pumps, and also

the hotwell pumps, are omitted, a saving in weight of 10 tons would probably be effected.

(*e*) *Arrangement of Feed Pumps.*—The main feed pumps should be placed in the forward parts of the engine rooms, and their speed should be regulated by float-control tanks. Pressure gauges should be fitted on the feed-discharge pipes in each firing space. The auxiliary feed pumps should be arranged in the stokeholds as at present.

(*f*) *Steam Pipes.*—The use of lap-welded wrought iron in preference to steel for steam pipes of internal diameters above 4 inches has advantage. Iron pipes are cheaper, more easily obtainable, as reliable and less affected by corrosion than steel pipes, and, in the larger sizes, a riveted covering strip over the weld is not required. In the arrangement of steam pipes large bends should be fitted where practicable, in order to take up the expansion of the pipes, and packed expansion joints should only be used where bends cannot be arranged for.

(*g*) *Arrangement of Main and Auxiliary Machinery in Engine Rooms.*—In the later cruisers which have been seen by the Committee, the machinery space is so restricted that the necessary examinations and adjustment of the working parts can only be carried out with difficulty. Where this condition exists, parts which are difficult of access cannot be examined as frequently as is desirable, and the machinery may not therefore always be maintained in a thoroughly efficient condition. As this inaccessibility of parts would be a matter of serious moment under the stress of actual war service, it is recommended that, in future designs, more engine-room space per horsepower should be provided than at present. In cases where this cannot be done, it is considered that provision should be made outside the main engine rooms for a portion of the auxiliary machinery.

(*h*) *Direction of Rotation of Propellers.*—The Committee have had under consideration the relative efficiency of outward and inward-turning screw propellers. The available information on this subject is very limited, but the results of some experiments, which have been placed before them, indicate that the balance of advantage is with outward-turning screws. It is considered that

this important subject should be investigated by careful experiments with H. M. ships.

14. In Section (*c*) of Paragraph 3 of the Letter of Reference the Committee are requested "to report on the advantages and disadvantages of Niclausse and Babcock and Wilcox boilers compared with Belleville, as far as the means at the disposal of the Committee permit; and also to report whether any other description of boiler has sufficient advantages over the Belleville, or the other two types mentioned above, as a boiler for large cruisers and battleships, to make it advisable to fit it in any of H. M. ships for trial." The Committee, in their Interim Report, mentioned four different types of large straight-tube boilers, viz:

(*a*) Babcock and Wilcox;
(*b*) Niclausse;
(*c*) Dürr;
(*d*) Yarrow large tube;

which they thought sufficiently promising for use in H. M. Navy, and they are still of this opinion.

15. These types have few of the disadvantages of the Belleville type, with most of its advantages. They all have "drowned" tubes, and the water level as shown by the gauges is practically the level of the water in the boiler; they do not require a much higher pressure to be maintained in the feed pumps than in the boilers, nor in the boilers than at the engines; the use of automatic feed regulators of an extremely delicate type is not necessary; the circulation is fairly well defined, and is much freer than in the Belleville; from such experience and evidence as the Committee have had before them, the loss of water will be much less than with the Belleville; and, finally, they appear to be much more likely than the Belleville to be free from accident under ordinary conditions of service.

16. In the course of their investigations, the Committee have watched the Babcock and Wilcox boilers fitted in the S. S. *Martello*, of the Wilson Line, employed in the Atlantic trade between Hull, Boston and New York, and copies of the reports of their inspections have from time to time been forwarded to their Lordships. These inspections have taken place at the end of every

round voyage for 14 months, and the Committee's opinion is that these boilers have stood the test of usage in the mercantile marine extremely well. The vessel has run about 91,000 miles since the boilers were put in, and has usually been less than a week in port at either end; the only repairs required have been those of the ordinary up-keep of any boiler, such as fire bars, brickwork, &c., and only six tubes have required renewal. This opinion is strengthened by the inspections of boilers of the same type fitted in the *Numidian*, the *Buenos Ayrean* and the *Turret Cape*. In the case of the last-named vessel, the boilers have been in use seven years, and cannot have been as well looked after as they would have been in the Navy, and their condition when examined recently was satisfactory. The Committee have also examined and tested boilers of the same type in H. M. S. *Sheldrake*, and find that, although they have been in use for four years, their condition is good and they have given little trouble.

17. Niclausse boilers were seen at Cherbourg in the *Variag*, a first-class cruiser of the Russian Navy, recently built by the Cramp firm at Philadelphia, which had steamed across the Atlantic only; also in the French pilot-school vessel *Elan*. Boilers of the same type in H. M. ships *Seagull* and *Fantôme* have been inspected: those in the *Seagull* are several years old, and have proved generally satisfactory.

18. Dürr boilers were seen under construction at Düsseldorf, while being fitted in place in H. I. M. S. *Prinz Heinrich* at Kiel; and in H. I. M. S. *Sachsen* at Kiel, after two years' work. Boilers of this type are being fitted in the *Medusa*.

19. Yarrow boilers of the small tube type have been seen in the new ship *Köningin Regenters*, of the Dutch Navy, and in the *Zenta*, an Austrian cruiser, which had recently returned from three years' service in Chinese waters. The Committee understand that the Yarrow boiler is being installed in the Dutch and Austrian Navies, with forced draft on both the closed stokehold system and the closed ashpit system with heated air supply. Two methods of heating the air supply are being fitted, one by means of tubes in the uptakes, and the other by fitting an outer case completely over the boiler and the uptakes, and passing the air supply through the space so formed.

20. Yarrow boilers are being fitted in the *Medea*, and were recommended by the Committee for use in combination with cylindrical boilers in some of the first-class cruisers of the *Devonshire* class. These boilers are of the large-tube type, with tubes 1¾ inches in diameter, and the Committee anticipate they will be more efficient and give better results on service than the small-tube type. The latest Yarrow boilers for the Austrian and Swedish Navies are having tubes of 1¾ inches diameter fitted.

21. The Committee have carried out a series of trials with the *Seagull* and *Sheldrake* and the *Espiègle* and *Fantôme*. The report on these trials is well advanced, and will be forwarded to their Lordships as soon as ready. The Committee would, however, point out that the trials with such small installations cannot be regarded as giving a true indication of what the same types of boilers would do in larger installations. As no large vessels in our Navy are, however, yet fitted with boilers of these types, the Committee thought it desirable to carry out trials in the vessels available. The results of these trials are satisfactory, and have confirmed the Committee in their opinion that Babcock and Wilcox and Niclausse boilers are suitable for trial on a larger scale in H. M. service.

22. The Committee were led to propose to their Lordships that Yarrow large-tube and Dürr boilers should be tried in the *Medea* and *Medusa*, respectively, as they understood that no ship in H. M. service was about to be fitted with these boilers, while several were with Babcock and Wilcox and Niclausse boilers, and it was thought desirable that trials of each of these four types should take place as soon as possible.

23. The work of fitting the new boilers in the *Medea* and *Medusa* is now well advanced, and the Committee hope that their trials will be begun shortly. A report on the results obtained will be forwarded to their Lordships as soon as possible.

24. While they will indicate whether Yarrow large-tube and Dürr boilers are safe and efficient steam generators, the Committee do not anticipate that the results of these trials, when taken together with the trials of the Babcock and Wilcox and the Niclausse boilers mentioned in Paragraph 21, will enable them to say whether either of these boilers can be "authoritatively rec-

ommended as a standard boiler for the use of H. M. Navy;" as the endurance of the boilers, the nature and extent of the defects which will be developed on actual service, the loss of efficiency after prolonged use, and the cost of up-keep can only be determined by lengthened experience.

25. In the ships of the *Monmouth* and *Devonshire* classes opportunity will be afforded for a very important comparison between ships of practically the same displacement and power, fitted with the same type of machinery, but only differing in the types of boilers fitted. The results obtained by these ships on trials and on actual service should contribute to a large extent towards solving the problem as to the best type of boiler for H. M. service.

26. During the course of their investigations the Committee have had the following types of water-tube boilers under consideration:

Belleville.	Thornycroft (small-tube).
Niclausse.	Thornycroft-Marshall.
Babcock and Wilcox.	Yarrow (small-tube).
Stirling.	Yarrow (1¾-inch tubes).
Dürr.	Blechynden.
Parker.	Normand.
Braby's Generator.	Lagrafel-D'Allest.
Weir.	Guilleaume.
Accessible.	Merryweather.
Myabara.	Montupet.
Vickers and Adamson.	Allan.
Lyall.	Du Temple.
Noble and Irving.	Schichau.
Bannister.	Schulz.
Hohenstein.	Okes-Serve.
Janson (American).	Dixon and Scott.
White-Foster.	Reed.
Thornycroft-Schulz.	Schutte.

27. Several of the above are small-tube boilers which are in use in small vessels of H. M. Navy, but, in the opinion of the Committee, they are unsuitable for vessels above the size of third-class cruisers. The following are, as already stated, those

considered to be the most worthy of attention as regards suitability for use in large vessels:

Niclausse.	Dürr.
Babcock and Wilcox.	Yarrow large-tube.

In addition to these four types, the Committee have had the following four under special consideration as being possibly suitable for large vessels:

Weir.	Thornycroft-Marshall.
Stirling.	Thornycroft-Schulz.

It is not recommended that a trial of either of these should be carried out at present, but the Committee suggest that their development for marine purposes should be carefully watched.

28. The trials mentioned in Paragraph 4 of the Letter of Reference, between the *Hyacinth* and a cruiser with cylindrical boilers, the *Minerva*, have been completed, and the full report on these was forwarded to their Lordships on November 27, 1901.

29. During the trials of the *Minerva*, the Committee recommended that retarders should be fitted in the boiler tubes, and it was found by trial that the efficiency of the boilers was considerably increased by their use. The Committee understand that the boilers of other ships in His Majesty's Navy have been fitted with similar retarders, and they think it right to state that retarders will be found in many cases to render existing cylindrical boilers more efficient and economical than they are at present.

30. From the evidence before the Committee, it appears that no type of water-tube boiler at present in use is, on general service, as economical as the cylindrical boiler; also, that a large percentage of the coal used is expended for auxiliary purposes in harbor. Until a thoroughly satisfactory type of water-tube boiler is obtained, the Committee therefore recommend that in large cruisers and battleships cylindrical boilers of sufficient power to work the auxiliary machinery, and to drive the ship at her ordinary cruising speed, should be fitted; the steam pressure should be the same for the water-tube and cylindrical boilers, and may conveniently be 210 pounds per square inch, so as to

give 200 pounds at the engines. By this means considerable saving in coal will be effected, with a corresponding increase in the radius of action and general usefulness of the vessel. The water-tube boilers could be kept clean and perfectly efficient, as they need only be used for driving the ship at high speeds, when economy of coal relatively is not so important. The cylindrical boilers should be fitted with retarders in the tubes, and with special means for circulating the water while raising steam.

31. Referring to Paragraph 6 of the Letter of Reference, in which "it was desired that, at a suitable time, an investigation into the causes of the high coal expenditure and machinery defects of the *Europa* shall be conducted under the direction of the Committee, and that she shall afterwards be put through such trials as the Committee think necessary," several members attended on board the *Europa* during her passage from Plymouth to Portsmouth, and afterwards a short trial was carried out under their direction. The Committee attended on board the ship at various times when the machinery was being opened out for inspection, and noted the condition of various parts; evidence was also received from the captain and three engineer officers who were on board the *Europa* during her voyage to Australia and back.*

A Special Committee, subsequently appointed by their Lordships to investigate the causes of the large coal consumption and the defects of the machinery and boilers of the *Europa*, has issued a report.

The machinery and boilers of this vessel have been so extensively refitted that, for trial purposes, they should be in as good condition as when new, or even in better. The results of trials should not, therefore, differ to any material extent from those usually obtained on the trials of the latest new ships fitted with Belleville boilers.

In these circumstances, it is considered that no useful purpose would be served by any further trial of the *Europa* by this Committee.

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*This evidence is given in pages 1 to 50 of the "Minutes of Evidence taken before the Committee Appointed by the Lords Commissioners of the Admiralty on Water-Tube Boilers."

32. From the information which has been brought to the notice of the Committee, it appears that water-tube boilers are being very little used in large ships belonging to the mercantile marine, and that their use in such ships is increasing very slowly. In the British mercantile marine the only type of water-tube boiler installed in ocean-going vessels is the Babcock and Wilcox, in some ships of the Wilson and the Petersen-Tate lines, and in three ships of the Allan Line; in these last, however, only one water-tube boiler is fitted in each vessel, to assist the original cylindrical boilers. In the United States mercantile marine Babcock and Wilcox boilers are used to a small extent, principally in the ships plying on the Great Lakes; Niclausse boilers are being installed in two very large ships of 15,000 horsepower. In France, Belleville boilers have been working in vessels of the Messageries Maritimes Cie. for many years. The Compagnie Générale Transatlantique have fitted two small vessels, one with Belleville and one with Niclausse boilers, in order to obtain comparative trials.

33. In the German Navy the Dürr boiler has been adopted for all large cruisers, while a combination of cylindrical and small-tube types is retained for battleships, and small-tube boilers only are fitted in the smaller cruisers. In the Dutch, Austrian and Swedish Navies the Yarrow boiler is very largely in use. In the French Navy the authorities seem to be undecided at present as to what boiler to adopt; it is understood that they have recently ordered two battleships, but have not decided on the boiler to be fitted. In the recent large cruisers ordered, the French seem to have chosen a different type of boiler for each ship, probably to obtain a trial of each kind. The Italian Navy have ordered a Niclausse installation for one of their new ships. In the American Navy, many Babcock and Wilcox boilers are in use, although recently Niclausse boilers have been ordered for four of the largest ships.

34. The Committee desire to record their indebtedness to Messrs. Thomas Wilson, Sons and Co., and more especially to Mr. Hide, the superintending engineer of that company, for the facilities offered to the Committee of inspecting the boilers of

the S. S. *Martello* continuously, and for the full information furnished on the subject of water-tube boilers in ships of the Wilson Line; also to Messrs. Johnson and Sergent, the superintending engineers of the Allan Line, for the facilities offered to the Committee of inspecting the boilers of the *Numidian* and *Buenos Ayrean;* and to Mr. Alexander Gray, of Newcastle, for facilities in inspecting the boilers of the *Turret Cape;* and to all these gentlemen for information given concerning the working of the water-tube boilers in these vessels.

They also acknowledge their special indebtedness to Mr. C. J. Wilson, F. C. S., who has given personal attention to the analyses of coal and flue gases for every trial made under their direction.

The Committee have received valuable assistance from Captain Coerper, of the Imperial German Navy, the German Naval Attaché, and Commander the Chevalier de Schwarz, of the I. and R. Austrian Navy, the Austrian Naval Attaché; also from Mr. W. H. Martin, of the Marine Engine Works, Flushing; from Mr. G. Lendecke, of the Stabilimento Tecnico, Trieste; and from Mr. Schiestl, a chief engineer of the I. and R. Austrian Navy.

They also desire to acknowledge the courtesy extended to them by the Admiralties of France, Germany, Russia and Austria, and by the naval commanders-in-chief and other officers at the various foreign ports visited, in affording them facilities for the inspection of boiler installations in various ships.

(Signed) COMPTON DOMVILE,
Admiral and Chairman.
JAS. BAIN.
JOHN INGLIS.
ALEX. B. W. KENNEDY.
J. T. MILTON.
JOS. A. SMITH.

M. E. BROWNING,
WM. H. WOOD,
Joint Secretaries.

May 28, 1902.

I agree with the foregoing report, except where modified by the following opinions:

Par. 6.—Burst Tube in Hyacinth.

This was certainly due to defective circulation, but the defect involves so seriously the question of safety with this type of boiler that it appears desirable to supplement the explanation given in the *Hyacinth, Minerva, Saxonia* report.

The appearance of the defective generator element when cut up longitudinally did not indicate that it had been short of water, either when the burst occurred or at any previous time, but did indicate that the tubes below the normal water level had not been overheated to an extent which left any appearance of it. The slight lime wash on those tubes was intact, and they were free from any trace of oxidation. The appearance of the tubes above the normal water level, however, clearly indicated that the circulation of mixed steam and water had been insufficient to prevent them getting red hot.

In my opinion, the explanation of this insufficient circulation is, that the element in question was in the wing, and therefore furthest away from the uptake, with one side of it shielded by the casing, and that the water stood comparatively quiescent at the normal level in that element, while the circulation was probably much more energetic in those nearer the middle of the fire grate.

Similar bursts have occurred in other ships, and are certain to occur more often as the boilers become older, and the tubes above the water level thinner from internal wasting. The *Hyacinth's* boilers had done very little work, and could not in any sense be considered old.

Choking of Minerva's Ferrules.

Messrs. Delaunay Belleville and Co., in their communication dated March 9, 1902, say in reference to the endurance trial of *Minerva:* "These retarders are probably not unconnected with

the choking of the ferrules with which the back ends of the *Minerva's* tubes are fitted."

They also, further on, draw attention to the following paragraph in the Committee's Report:

"The openings in the ferrules were found, on examination at Gibraltar, to be choked up across half or three-quarters of their area by a thick, hard, brown slag, which also coated the surface of the tube plates, and which was not removed until access was gained, after cooling, to the combustion chambers."

They further add:

"This circumstance shortened the duration of the trial, although the *Minerva* had 39 tons of coal in her bunkers."

These are points of such importance as affecting the use of cylindrical boilers in H. M. Navy that further explanation is desirable.

Having examined one of the back tube plates at Gibraltar before it was cleaned, I am of opinion that the accumulation of slag resulted from the cap parts of the ferrules becoming overheated, and the fine particles of scoria carried by the draft becoming burned onto them, ultimately forming a smooth vitrified coating all over the plate, with small elliptic apertures at each tube end.

This was a serious state of affairs, and it effectually brought the trial to a conclusion. It is, however, entirely at variance with experience in cylindrical boilers of merchant steamers using forced draft.

The *Minerva* had only been under weigh for about 152 hours, and the average rate of combustion was only 22.36 pounds per square foot per hour.

Many hundreds of steamers are making voyages to all parts of the world with closed ash-pit forced draft, heated air and higher rates of combustion than this. In those ships no ferrules of any kind are fitted, and retarders are invariably used. Coating of the tube plates with slag is unknown, and "bird-nesting," which is quite a different thing, only occurs, if the tubes are leaking, from the tube plates being greasy or dirty on the water side—a condition of affairs which is not permitted, because it affects seriously the earning power of the ship. The tubes are 2½ inches

in external diameter, and are in some cases pitched as close as $3\frac{5}{8}$-inch centers, both vertically and horizontally. The tube plates are also in very many cases thicker than those in the *Minerva*, being for working pressures of 200 pounds and upwards.

The retarders had, in my opinion, no connection with the choking of the ferrules in the *Minerva*, but these caused the formation of the coating of slag referred to.

Pars. 7 and 12 (c).

Serious defects, not only in the casings, but also in the structural parts of the *Europa's* boilers were apparent on that ship's return from Australia, September, 1900. Admitting the correctness of the statement that the burning of the casings may be reduced to a minimum by skillful stoking, that does not afford much cause for satisfaction, as the minimum appears likely to prove formidable, and as it is improbable that in time of war the stoking will be as good as it is now. Experience of firemen in the merchant service leads me to the conclusion that, if men have to be drawn from that source, they will prove much less skillful than trained navy stokers. These considerations point to the desirability of adopting for warships a type of boiler which is not readily damaged by unskillful working.

Damage to the framing of a water-tube boiler may be avoided by arranging it so that even with considerable wear and tear of the brickwork it remains protected. Up-keep on the casings may be reduced by an increase in the weight of brickwork, and non-conducting material, by using thicker plating, and in some cases by leading the air on its way to the ash pits through the space formed between an inner and an outer casing.

Par. 13 (a).

While agreeing with the desirability of increase of stroke and reduction of revolutions where considerations of weight and space permit, I desire to add that the running on full-power trial of engines designed in accordance with recent Admiralty practice, developing 30,000 indicated horsepower collective, with a stroke

of 4 feet, and at 125 revolutions per minute, was entirely satisfactory.

Par. 13 (*b*).—*Condensers.*

I agree, but desire to add:

The objections to fitting two main condensers in each engine room are these:

Increased weight in centrifugal pumps, pipes, connections and circulating water carried, due to the necessity for fitting two main centrifugal pumps (each with an engine) in each engine room, to ensure equal delivery to both condensers.

Increased weight, due to the large eduction stop valves on the low-pressure cylinders with the connecting eduction pipes.

The risks of mistakes being made, in working the valves for the pumps and those between the condensers and the engines.

The arguments in favor of the arrangement are:

That if one half is leaking and the other half tight, the engines may be worked up to half power while the defective condenser is under repair.

That in action, if one-half condenser or its connections is damaged in each engine room, the ship can still steam at half power.

In considering this last argument, the fact that the additional connections necessitated by double condensers add to the risk of disablement should be kept in view.

In the latest cruisers with inward-turning propellers and the working platforms in the middle line, it is impossible to find space for one large condenser between the engines and the ship's side. When, however, the machinery is arranged for outward turning, with the two L.P. engines together aft, the condenser would, as in former designs, be placed aft also.

As evidence that, apart from arguments based on purely Service requirements, very large single condensers give satisfactory results, where the details of construction are in accordance with merchant service practice, mail steamers on the Atlantic may be instanced, of about 35,000 horsepower collective, which have only one main condenser in each engine room. It is submitted

that the balance of advantage might be found on the side of single condensers, with their simpler connections, and with thicker tubes, tube plates and ferrules, and deeper packing.

Considering that one of the most serious difficulties in connection with condenser leakage is perforation of the tubes, it is submitted that this subject is one upon which the assistance of chemical and metallurgical experts of eminence might with advantage be sought.

Par. 13 (*c*).—*Jackets.*

I agree, but desire to add—

Separate liners should in all cases be fitted on engines above the size of those in destroyers, even when jacketing is not adopted. The draining of the jackets should be done by a reliable type of trap, and not by hand; also the steam supply to the jackets should be regulated by separate reducing valves of suitable type.

Par. 13 (*d*).—*Pumps.*

I agree, but have to add that the saving of about 10 tons in weight is upon the following basis:

Two single-acting lever air pumps on each set of main engines, 30 inches in diameter by 13-inch stroke, replaced by a pair of single-acting independent pumps in each engine room, the diameter being 33 inches, the stroke 21 inches and the speed, at full power, 25 double strokes per minute.

Par. 13 (*e*).—*Arrangements of Feed Pumps.*

I agree, but have the following additional recommendations to make:

The pumps should be of the vertical direct-acting (not duplex) type, with packed water piston and blow-over steam valve, and the following points of design should have attention:

The pump barrel should be gun metal, with a liner so arranged that a replace one can be readily put in at sea without serious dismantling of connections. These renewable liners should be cast of a special alloy of gun metal which will wear well with the packing of the water piston. That piston should be fitted

to the pump rod with a taper and nut below. The pump rod should be hard-rolled bronze, and it should be coupled to a steel steam piston rod. Bronze rods have been found to break in the steam cylinder, at the bottom of the thread of the piston nut, and steel rods have failed in the pump barrel from corrosion.

Where valve levers having sliding surfaces in the crosshead are used the sliding ends should be rectangular and fitted with adjustable gun-metal slips and oil cups; otherwise, with a heavy steam pressure on the slide of the shuttle valve, it has been found that the lever sliding surfaces seize.

Saving of weight over and above that referred to in Par. 13 (*d*) of Report would result from dispensing with the hotwell tanks, feed tanks and grease-filter tanks as at present arranged. The independent air pumps might lift the water direct from the condenser bottom to the upper part of the grease-filter tank, which might, if desired, be built into the ship, and which should have sufficient capacity, independent of the filter proper, to admit of sudden increase of water delivered due to increase of speed of ship. The filtered water would gravitate from the level of the top of the filter proper direct to the float-control tank, which should have the float balanced by a spring or weighted lever, and which should be placed at such a level that the water will gravitate from it into the suction chests of the feed pumps.

The auxiliary feed pumps should have their steam connections also arranged for working under float control.

Par. 13 (f).—Steam Pipes.

I agree, and recommend further that where flanges are not scraped and faced, corrugated-metal jointing washers should be used.

With further reference to the latter part of Section *b* of paragraph 3 of the Letter of Reference, I desire to add the following:

1. *Standardization.*

Submitted that the main and auxiliary machinery, and the connections, in ships of the same class, for which contracts are

placed within periods the duration of which may be hereafter determined, should be identical. This would admit of interchange of spare parts, and would render it easier to train the engine room and stokehold complements.

With advance in machinery design, it would be necessary to avoid adhering for too long a period to one standard.

2. *Type of Propelling Machinery.*

Submitted, that the four-crank engine with three-stage expansion, as now adopted in the Service, is preferable to the three-crank three-stage type, because it not only admits of more perfect balancing, but also keeps down the weight of the low-pressure pistons. It is further submitted that to admit of accurate data being obtained of the steam consumption of four-stage expansion engines at cruising powers, it is desirable to fit a ship with four-crank balanced engines of that type.

3. *Cylinder Liners, &c.*

Submitted, that whereas in the merchant service the initial pressures up to 215 pounds, and piston speeds of 900 feet per minute, high-pressure cylinder liners of hard, close-grained, cast iron are found quite satisfactory, if a suitable type of cast-iron piston packing be adopted, I consider that steel high-pressure liners, as reverted to in H. M. ships, are open to objection: first, because there are few firms which can produce them sound, the price being therefore high, and there being also delays in delivery; second, because they necessitate the use of bronze packings, which may wear rapidly; and, third, because they introduce some difficulties in construction from the difference in the coefficient of expansion due to heat between steel and cast-iron. It is submitted that the brands, and the definite proportions of those brands, of cast iron to be used for all wearing parts, such as cylinder liners, slide valves, valve faces, &c., exposed to steam should be specified.

4. Design of Cylinders and Steam-Distribution Valves.

Submitted, that this, as carried out by first-class makers for H. M. ships, leaves little room for improvement. Piston valves, however, are open to objection for the following reasons:

If fitted with packing rings which are free to expand, the lanterns may become worn for the travel in use at low cruising powers, with the result that when the travel is increased by linking out for full power, the packing rings may catch, involving risk of accident. In mercantile practice this has led to the almost universal abandonment of packings which are free to expand while under steam. The type of ring generally in use can be made larger by putting in slips at the partings, the combination forming a block piston, which is not reasonably steamtight.

The port clearance space with piston valves is excessive, and the amount of wire drawing, due to passing steam through the lantern ports, is considerable.

The cylinders and casings, with double piston valves especially, are complicated, and therefore objectionable from the point of view of obtaining sound castings.

For high-pressure and medium-pressure cylinders, the type of valve which is being fitted to the high-pressure cylinders of the *Medea* and *Medusa* has been found to give excellent results in ships of the Dutch Navy and in merchant steamers. It has the further advantages over a piston valve that the travel for a given opening is less; and that in the event of accumulation of water in the cylinder, the valve and saddle will blow off the face, and go back to place under the action of the saddle springs, thus forming an escape valve of large area.

For low-pressure cylinders, double or treble-ported valves, with relieving rings having efficient packing, and a separate pipe connection to the condenser, are satisfactory. For heavy slide valves of fast-running engines, steam-driven assistant cylinders have proved more efficient than balance cylinders of the usual type.

5. Pistons and Packing Rings.

Submitted, that cast-steel pistons as in general use in H. M. ships are satisfactory. The following points of design are based on extended experience:

The taper of the piston-rod cone fitting to the piston should not be less than 4 inches per foot on the diameter, and the rod should have a collar on it bearing when the cone is thoroughly home. The piston-rod nuts for a mild-steel rod should be forged from selected scrap iron. This practice should be carried out in the case of all large steel bolts, the reason being that there is less risk of the threads biting than if both are of mild steel.

The bearing surface of the cast-iron junk ring on the cylinder wall should be as deep as practicable. This ring should be so designed that with the greater expansion of the steel piston there is no liability to split. The steel flange of the piston should be kept $\frac{1}{16}$ inch clear of the cast-iron cylinder wall.

The cast-iron packing rings should be comparatively narrow in bearing surface against the cylinder wall. They should have vertical springs to press them against the piston flange and junk-ring face, and radial springs to set them out. They should also be fitted with strong tie plates which are readily adjustable.

Instead of junk-ring collar studs, with gun-metal nuts and a wrought guard ring, as fitted in the service, the general practice in the mercantile marine is to use turned-steel pins, tapped into gun-metal bushes which are screwed into the cast-steel piston. These pins have square heads bearing on faced soft brass washers; each pin is marked to place, and they are screwed down with a box spanner and a long wrench. This, it is submitted, is a more reliable arrangement than that used in the service. The exact description of cast iron for junk rings and packing rings which will wear well with a given mixture of metal in the cylinder liner, is a point of great importance.

6. Piston-Rod and Valve-Spindle Packings.

For piston rods it is submitted that a suitable design of metallic packing should be exclusively adopted, and that for the same diameters of rods and steam pressures the packing and springs for it should, in future work, be standardized throughout the service.

Also, that for valve spindles a standard make of fibrous semi-metallic packing should be adopted.

The objects of such standardization are efficiency and economy, with, at the same time, uniformity in the operations to be carried out by the artificers. The satisfactory performance of these, as regards adjustments of packings, are essential to the successful running at full power of warship engines.

7. Fitting of White-Metal Crosshead-Pin Details.

Submitted, that white metal in all reciprocating parts, such as guide shoes, should be specified to be machined and fitted to place, and not simply cast in; also that all crosshead pins and other bearings upon which the bushes only partially rotate should be specified to have flats machined on the sides to reduce unequal wear.

8. White Metal.

Submitted, that for lining bearings, crank-pin bushes and other parts, exclusive of crosshead bushes, the following alloy has, in hard ocean steaming, been found, after extended experience, to give good results: 12 parts tin, 1 part copper, 1 part antimony, mixed in the following way: six parts tin alloyed with 1 part of antimony, and 6 parts tin with 1 of copper, and the two mixed together.

For lining crosshead brasses the following harder alloy has been found to give good results: 85 per cent. tin, 5 per cent. copper and 10 per cent. antimony.

9. Nickel-Steel.

The annexed sheet (see Table I, herewith) gives the results of tests and analyses of a description of nickel-steel which is coming extensively into use in the machinery of warships for foreign powers, and also in that for high-powered mail steamers. These tests are from shafting made under the subscriber's supervision. It is submitted that steel of this class offers advantages for forgings of warship engines where lightness is important, but that careful annealing after forging is essential.

10. *Valve Gear.*

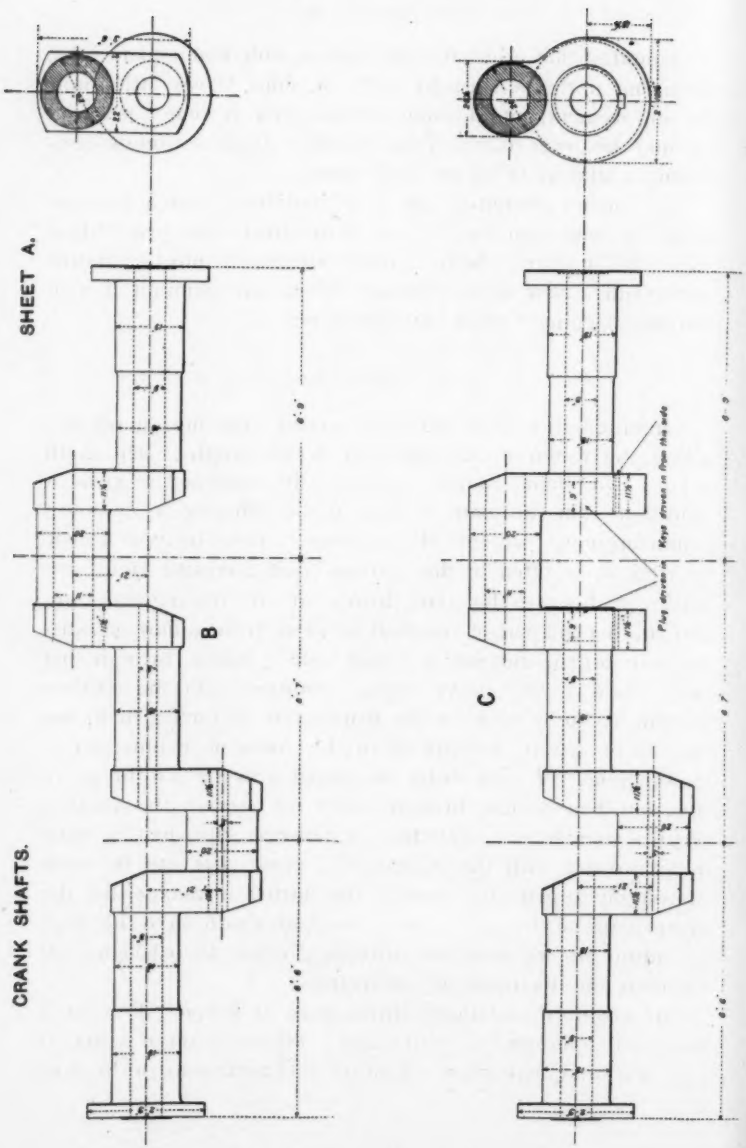
Submitted, that adjustable-link motion, with double-plate links, according to the best design in H. M. ships, leaves little room for improvement, but advantage would result in some cases from running the lower halves of the eccentric straps in troughs containing a mixture of oil and fresh water.

It is further submitted that it is desirable to watch developments in connection with a type of modified valve gear (Patent No. 3,761, of 1901), which is being introduced into locomotive work, with a view to ascertaining whether the adoption of it in warship machinery offers any advantages.

11. *Crankshafts.*

Submitted, that in second-class cruisers, and ships above that power, the design of the crankshaft in two lengths, each length having two cranks almost diametrically opposite, is open to objection from the point of view of the difficulty of obtaining sound forgings. Design "B" (see below) shows the type of shaft referred to, as fitted in the cruisers *Kent*, *Lancaster* and *Cornwall*. In this case the crank throws are so close together fore-and-aft, that the part of the shaft between them cannot be satisfactorily forged, and only a 5-inch hole is bored through that part. Also a very heavy ingot, compared with the finished weight, has to be used for the manufacture of such a shaft, and the risk of defects showing up in the course of manufacture is considerable. If such shafts are forged with the two throws in line, and then twisted through nearly 180 degrees, the result as regards soundness is doubtful. If, however, the shaft is made in accordance with the design "C," every part can be more thoroughly forged, and there is the further advantage that the manufacture of the pieces can be proceeded with up to the stage of cutting the key beds and shrinking, before the balancing calculations and diagrams are completed.

The weight of one double-throw piece to design "B" is 10.14 tons, and to design "C," 11.13 tons; difference, .99 of a ton, or 3.96 tons total increase of weight on the crankshafts in the ship.


SHEET A.
CRANK SHAFTS.
B
C
Keys driven in from this side
Plug driven in

The shafts would be still more reliable if all the cranks were shrunk on, and the extra weight in the ship would be 8.84 tons, compared with design "B." It is submitted that built shafts of this type are preferable to what is specified for the *Devonshire* class, where there is a coupling between each pair of cranks, involving considerable increase in the total length of the machinery.

12. Grease Filters.

If these are arranged as suggested above (Paragraph 13*e*), the amount of surface might, with advantage, be increased 50 per cent., compared with recent Admiralty specifications. For efficiency, the governing condition is as large a surface, and, therefore, as low a speed of flow through the medium as considerations of weight and space permit. Towelling in three strata as used in the Service is on the whole satisfactory. From the point of view of keeping down weight of construction, the 30-pound test pressure which has been specified for grease filters, irrespective of the working pressure to which they can be exposed, is undesirable.

13. Centrifugal Pumping Engines.

Submitted, that these for main and auxiliary condensers, as fitted in H. M. ships, are satisfactory, where not also used to drive air pumps. The steam cylinders should be of sufficient size to do the maximum work with not more than 120 pounds initial steam pressure. With single-crank engines the exhaust should be arranged with a separate change valve to the condenser, as, when running at moderate speed, with maximum back pressure on the closed exhaust system, there is risk of stopping on the dead centers. Balanced slide valves are less wasteful of steam than piston valves, and involve less risk of breakdown due to water being thrown into the cylinders from long ranges of pipes by the motion of the ship. A slide valve will blow off the face, whereas a piston valve may lock the water into the cylinder.

14. Auxiliary Steam Pressure.

Submitted, that the balance of advantage is in favor of a pressure not exceeding 120 pounds.

15. Fire and Bilge Pumps.

Submitted, that, as duplex pumps give a more uniform delivery than double-acting single-barrel pumps, it is desirable to fit them in preference to the latter, where used for fire-extinguishing purposes only. Where, however, the same pump may be used for bilge pumping, fire and sanitary work the balance of the advantage lies with the single-barrel type, provided that it is not of so small a size that there is trouble from the shuttle valve sticking. The pump barrels in any case should be of gun metal, with easily-renewable gun-metal liners and gun-metal valves. The pump pistons should have ebonite packing rings, where cold, clean, fresh water, or sea water, is to be pumped. For hot or impure water white-metal packings, which can be readily renewed, are preferable.

16. Crank-Pit Pumps.

Submitted, that it is desirable in large ships to fit a steam pump in each engine room, to be used for this work when the ship is under weigh, and that it should be of the duplex type, having gun-metal pumps, with the pump pistons packed with white metal, and with gun-metal valves. Each pump should be steam controlled by a float sunk into a small well in the double bottom, at the lowest part of the crank pit. That the pump may have to be at some distance from the steam-control cock is immaterial.

17. Closed Exhaust Evaporators and Distillers.

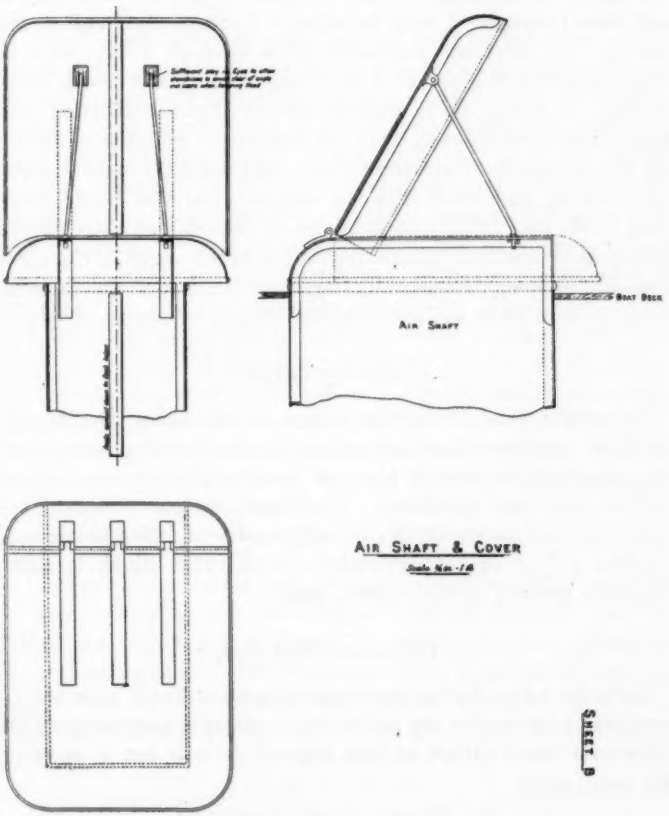
Submitted, that the closed exhaust system, and the evaporators and distillers for working in connection with that system, and with live steam, according to the latest Service practice, are satisfactory. If auxiliary condensers are not fitted, or are not used when under weigh, the coil drains would be led to the main condensers.

18. Dynamo and Fan Engines.

Submitted, that these as fitted are satisfactory, except that the cylinders should be kept of such size that the initial steam pressure does not exceed 120 pounds. Slide valves are preferable to piston valves for the reasons given in clause 13 above.

19. Air Supply to Fans.

Submitted, that when permanent cowls are abolished, the question of efficient downcasts to the fans requires consideration, as



canvas windsails are not satisfactory. One solution of the question is a rectangular steel trunk having a hinged flat top (see engraving above).

20. Auxiliary Condensers.

Submitted, that except where double-main condensers are used, these as at present fitted are satisfactory, but that the Service system of keeping one in use when the ship is under weigh, and even throughout long voyages, is uneconomical and unnecessary. In merchant steamers which have in some cases as many auxiliary engines as a first-class cruiser, and which have to stop at calling ports, with the electric-light installation and many other auxiliaries at work, no difficulty is found in exhausting all these to the main condensers, both when the main engines are running, and when they are stopped, and this holds good even in the case of air pumps driven off the main engines. With independent main air pumps, regulation of the speed of the electric-light engines or other auxiliaries on account of the vacuum being broken when the main engines stop is, of course, obviated.

21. Steering Engines.

Submitted, that the Service system of exhausting this to the auxiliary condenser is, as pointed out in the preceding paragraph, uneconomical, because it involves running the pumps in connection with that condenser. Considerable steam economy results from the comparatively recent practice of fitting to steering engines a type of supplementary cut-off valve, which is automatically worked by the control gear.

22. Evaporator Feed Pumps.

Submitted, that double-crank pumps with ordinary slide valves worked by eccentrics are preferable to direct-acting pumps with blow-over steam valves, as that type of valve is apt to stick in the small sizes.

23. Electric-Driven Auxiliaries.

Submitted, that motors are suitable for driving fans of moderate size, small centrifugal pumps, and in some situations geared crank pumps, but that they are not suitable for use with capstans, hoists, winches, or other appliances essential to the safe

handling or fighting of the ship, and in which the load may exceed the power of the motor, as in that case the fuse may be burned out or the armature damaged at a critical time.

Par. 19.—Heated Air Supply to Large-Tube Yarrow Boilers.

Considering that with this type of boiler the course of the gases to the uptakes is very direct, at full power overheating of the upper parts of the casings may prove a source of trouble. For this reason the systems of closed ash-pit forced draft, with air heaters and casings, which are described, may be found advantageous. In cylindrical boilers having air-heating tubes in the uptakes, buckling of the lower tube plates of these sometimes results from "flaming." This causes leakage of the air under pressure into the uptakes, with resulting falling off in the performance of the boilers. That points to the desirability of using with Yarrow boilers either a type of tube air heater in which the tube plates are not exposed to direct impact of the hot gases, or one such as that last referred to in Par. 19, where possibly the casing plates might buckle to some extent and still keep tight at the landings, if close riveted, with a strand of asbestos between. The arrangement of double casing has the further advantage that it secures cooler stokeholds.

Par. 21.

I am of opinion that a type of water-tube boiler which involves in its construction machine work of extreme accuracy, and for which the refinement of gauges is necessary, may ultimately prove less suitable for H. M. ships than a type which does not require for its manufacture and uptake machine tools of a character differing greatly from those generally used in boiler making.

Pars. 26 and 27.

The Committee's attention was, by the terms of reference, not specially directed to "Express" boilers, and therefore no such examination has been made into the relative merits of those most in use which warrants any very definite expression of opinion.

Thornycroft-Schulz Boiler.

In Progress Report, 1901, at page 38, reference is made to the boilers of this type which were examined under construction at the Germania Works, Kiel, for a German battleship, to be used in combination with cylindrical boilers.

It appears from evidence put before the Committee (pages 282 to 286, Minutes) that this type of boiler is in use in the battleships and cruisers of several other foreign powers.

Where the following points of design are carried out, I consider it suitable for use in combination with cylindrical boilers in ships above the size of third-class cruisers in H. M. Navy:

1. The tubes to be of not less than 1⅜ inches in external diameter, and not less than No. 8 L. S. W. G. thick.

2. The curvature of the tubes to be such that a flexible cutter can be passed through them for the removal of scale.

3. The arrangement of the tubes to be such that only a small percentage discharge above the water level, and that there are no air locks in them when the boiler is filled right up.

Stirling Boiler.

This, in its land form, is coming extensively into use. In its marine form it possesses several good features, and has been at work on land and also in a sea-going vessel for some time with success.

Weir Boiler.

This also has been at work on land for some considerable time with success, and when submitted to a careful examination by the Committee was found to be in good condition.

Thornycroft-Marshall Boiler.

This type, with large single-back header, has also been at work on land for some considerable time with success.

I am of opinion that these three boilers, which are all of the large-tube type, and which have passed the experimental stage, are worthy of trial in vessels attached to the dockyards where their performance could be carefully watched, and where trials

could be made at sea for extended periods under Service conditions.

Schichau Boiler.

This I consider has features of design which warrant that its further development should be closely followed.

Par. 29. Retarders.

I would suggest further that a trial of retarders without ferrules be made in an existing ship having suitable cylindrical boilers, and in which efficient grease filters are fitted.

Par. 30—Combination Installations.

Where in these a type of water-tube boiler is used which is fairly light, and which admits of considerable forcing, I consider that the balance of advantage is in favor of combining with these about 30 per cent. of the full power in cylindrical boilers rather than about 20 per cent. The larger proportion would avoid forcing unduly the cylindrical boilers, and would admit of the water-tube boilers being less often used, which would not only economize coal, but also reduce wear and tear on the fire-brick work and casings. At the same time it would admit of carrying out thoroughly the very careful and systematic cleaning and overhauling which is essential if boilers of that type are to be maintained over extended periods in a reliable condition for full-power steaming.

I consider it undesirable to limit the loaded pressure on such combinations to 210 pounds, as designs which are before their Lordships show that 220 pounds is quite practicable in cylindrical boilers for a first-class cruiser.

Howden's Forced Draft.

Considering the very extensive adoption of this system in the mercantile marine, and its proved advantages, I am of opinion that if carried out in accordance with certain designs which are before their Lordships for cruisers of the *Devonshire* class, it would give better results in those ships than closed-stokehold forced draft for the cylindrical boilers.

TABLE I.—TESTS OF NICKEL-STEEL SHAFTING.—A, B, C, D AND E MADE SUPERVISION OF BOTH THE BOARD

Description of shafts.	A.—Crank.		B.—Thrust.	
Finished diameter, in inches	10½		10½	
Lloyd's number and mark	6,862 A	B 6,862 A	6,869	6,859 B
End of ingot forged tests taken from	Top	Bottom	Top	Bottom
Tensile Tests.				
Date	17, 1,'02	19, 20,'2	17, 1,'02	19, 2,'02
Dimensions of bar, in inches:				
Diameter	.75	.74	.75	.74
Area	.441	.43	.441	.43
Ultimate stress, in tons:				
Total	17.1	15.8	16.4	15.8
Per square inch	38.7	36.7	37.1	36.7
Elongation in per cent. of original	28	32	33	30
Elastic limit, in tons:				
Total	10	11	10	11
Per square inch	22.6	25.5	22.6	25
Contraction of area, in inch:				
Least diameter	.55	.52	.51	.55
Area	.237	.212	.204	.237
Per cent. of original	46.2	50.6	53.7	37.9
Appearance of fractures	Silky	Silky	Silky	Silky
Fatigue Tests.				
Date	17, 1,'02	...	17, 1,'02	...
Dimensions of bar, square section, inches	1.25	...	1.25	...
Falling weights, in cwts	10	...	10	...
Drop, in inches	12	...	12	...
Distance of supports apart, inches	6	...	6	...
Number of blows to produce fracture	60	...	63	...
Number of blows after fracture to break	8	...	11	...
Lloyd's number and mark	6,862 A	B 6,862 A	6,859	6,859 B
End of ingot forged tests taken from	Top	Bottom	Top	Bottom
Bending Tests.				
Date	17, 1,'02	19, 2,'02	19, 2,'02	19, 2,'02
Dimension of bar, square section, inches	1	1	1	1
Inside radius of bend, in inches	¾	¾ full	7/8	¾ full
Appearance of bend	Good	Good	Good	Good
Sign of fracture	None	None	None	None
Analysis Made in the Laboratory of the Steel Manufacturer.				
Silicon	.075	.089	.075	.068
Sulphur	.046	.038	.044	.043
Phosphorus	.040	.040	.039	.044
Manganese	.065	.725	.692	.600
Nickel	3.25	3.25	3.24	3.18
Carbon	.290	.280	.285	.280

UNDER THE SUPERVISION OF LLOYD'S REGISTRY; F MADE UNDER THE OF TRADE AND LLOYD'S REGISTRY.

C.—Line.		D.—Line.		E.—Propeller.		F.—Thrust.	
10		10		10¼		19¼	
6,860 Top	6,860 B Bottom	6,861 Top	6,861 B Bottom	6,862 Top	6,862 B Bottom	6,916 T Top	6,916 B Bottom
17, 1,'02	19, 2,'02	19, 2,'02	19, 2,'02	17, 1,'02	19, 2,'02	20, 12,'02	20, 12,'01
.75	.74	.74	.74	.75	.75	1	1
.4411	.43	.43	.43	.4411	.4411	.795	.785
16.2	16.2	15.5	15.4	16.5	16.4	28.7	28.7
36.7	37.6	36	35.8	37.4	37.1	36.5	36.5
30	30	34	34	30	29.5	24	24
9.8	10.3	10.6	11	9.8	11.1	...	...
22.2	23.9	24.6	25.5	22.2	25.1	...	...
.51	.52	.48	.51	52	.51	.73	.7
.204	.212	.181	.204	.212	.204	...	...
53.7 Silky	50.6 Silky	57.9 Silky	25.5 Silky	51.9 Silky	53.7 Silky	46.7 Silky	.51 Silky
17, 1,'02	...	21, 2,'02	...	17, 1,'02	...	20, 12,'01	...
1.25	...	1.25	...	1.25	...	1.25	...
10	...	10	...	10	...	10	...
12	...	12	...	12	...	12	...
6	...	6	...	6	...	6	...
79	...	65	...	55	...	59	...
6	...	5	...	13	...	8	...
6,860 Top	6,068 B Bottom	6,861 Top	6,861 B Bottom	6,862 Top	6,862 B Bottom	6,916 T Top	6,916 B Bottom
17, 1,'02	19, 2,'02	19, 2,'02	12, 2,'02	17, 2,'02	19, 2,'02	20, 12,'01	20, 12,'01
1	1	1	1	1	1	1.25	1.25
⅜ Good None	⅜ Good None	5/16 Good Appearing inside	7/16 full Good None	⅜ full Good None	⅜ bare Good None	... Good None	... Good None
.089	.094	.056	.06	.073	.084	.104	.112
.044	.042	.054	.052	.049	.045	.043	.038
.041	.038	.048	.046	.037	.036	.042	.038
.083	8.36	.55	.57	.781	.8	.66	.638
3.3	3.44	2.98	3.	3.38	3.45	3.06	2.96
.275	.265	.29	2.85	.3	.285	.32	.288

I would further suggest that this system should be applied, not only in a cruiser, but also in a battleship specially designed for an installation consisting entirely of modern high-pressure cylindrical boilers. This would admit of comparisons being made, not only with similar ships having all water-tube boilers, but also with those in which different combinations of water-tube and cylindrical boilers are fitted.

Par. 31. Europa.

The results of the short trial made by this Committee on the ship's return from Australia are given in the Appendix to Evidence. I consider that the high coal expenditure and machinery defects were due principally to the fact that the engines and boilers were not in an efficient state when the ship sailed for Australia, and that during the voyage the falling off in efficiency was altogether exceptional. The causes are fully referred to in the evidence taken by this Committee.

May 28, 1902. JOHN LIST.

NOTES.

LETTER FROM MESSRS. DELAUNAY, BELLEVILLE & CO., COMMENTING ON THE REPORT OF TRIALS OF H. M. S. *HYACINTH* AND H. M. S. *MINERVA*.

SAINT DENIS (SEINE), *9th March, 1902.*

SIR: We have the honor to submit to your notice the following observations which have occurred to us in reading the recent Report by the Committee on Water-Tube Boilers on the trials of the cruisers *Hyacinth* and *Minerva*. We should be obliged to you if you would kindly place these observations before the Lords Commissioners of the Admiralty.

Efficiency of the Boilers.—It appears to us of the greatest importance, in view of the controversies which have raged in print on the subject of the efficiency of Belleville boilers, to, in the first place, point out the fact that the Committee recognize that these boilers show greater economy than the boilers under comparison with them.

The figures in lines 46, 47 and 49 of Table XXV, annexed to the Report, leave no doubt on this point. We give them below:

Table XXV.	*Minerva.*	*Hyacinth.*
Line 46. Thermal efficiency of the boilers:		
At about 2,000 H.P.	69.7	77.2
5,000 H.P.	68	71.8
8,000 H.P.	61.4	73.3
Line 47. Actual evaporation per pound of coal under the conditions of the trial:		
At about 2,000 H.P.	8.56	9.65
5,000 H.P.	8.84	9.33
8,000 H.P.	7.93	9.39
Line 49. Equivalent evaporation (per pound of coal) at a steam and water temperature of 212 degrees Fahrenheit:		
At about 2,000 H.P.	10.26	11.46
5,000 H.P.	10.33	11
8,000 H.P.	9.27	11.03

The report summarizes these observations in the following words (page 8, line 35):

"The thermal efficiency of the *Hyacinth's* boilers was in each case greater than that of the *Minerva's* at the same power, and the evaporation per pound of coal from and at 212 degrees varied, of course, in the same way. The difference is considerable at 2,000 H.P., small at 5,000 H.P., and very great at 8,000 H.P."

With the object of lessening this inequality in results, and in order to better regulate the quantity of air passed through the fires in the *Minerva*, the Committee had spirals of thin sheet iron (called "retarders") inserted in the boiler tubes.

The result, it is true, was somewhat better, but it was not equal to that obtained on the *Hyacinth*, as stated in the Report. The results on the *Minerva*, with retarders, are still notably inferior to those obtained on the *Hyacinth*, as the following figures, extracted from Table XXV, show:

Table XXV.	*Minerva.*	*Hyacinth.*
Line 46. Thermal efficiency of boiler, per cent.....	68.4*	73.3
Line 47. Actual evaporation per pound of coal, pounds.....	8.84	9.39
Line 49. Equivalent evaporation from and at 212 degrees Fahrenheit, pounds.....	10.34	11.03

* With retarders.

It may be here remarked that these retarders are probably not unconnected with the choking of the ferrules with which the back ends of the *Minerva's* tubes are fitted, and of which mention will be made further on. As a matter of fact, the Committee does not state whether similar obstructions have been experienced during voyages of the *Minerva* prior to the use of these retarders.

While these retarders increased the efficiency of the *Minerva's* boilers, without, however, making it equal to the efficiency of the *Hyacinth's*, this relative improvement seems to have been gained only at the expense of an inconvenience elsewhere.

Calorimetric Tests (*Dryness of Steam*).—Before leaving this question of efficiency it will be well to say a few words about calorimetric measurements made on the two cruisers during the trials, in order to ascertain the wetness of the steam.

The Report shows that, from measurements made by a Carpenter calorimeter on the *Hyacinth* at less than 8,000 H.P., the wetness was so small that its average value was negligible (page 10, line 60), but that when the horsepower was between 8,000 and 10,000 the proportion of water indicated by the apparatus as contained in the steam was 4.7 per cent. and 6.4, respectively (*ib.*, line 63). On the *Minerva*, on the contrary, the steam at these different horsepowers was found to be practically dry.

As a general rule, calorimetric observations are of an extremely delicate nature, but one may be certain that the readings of the instrument give results here which cannot be correct.

In the first place, different positions were chosen in the *Minerva* and *Hyacinth* for making the connections between the calorimeter and the steam to be tested. In the *Minerva* the calorimeter (page 6, line 14) was connected to the steam pipe between the regulating valve and the high-pressure valve chest of the port main engines; in the *Hyacinth* it was connected to the steam pipes in No. 5 stokehold on the boiler side of the separator. To render the results comparable it would have been necessary, in the *Hyacinth*, to make the connection near the high-pressure valve chest, as was done in the *Minerva*, for it is there only that the steam, purified in the separator, and "wire-drawn" in the reducing valve, is in the condition in which it is used in the engines. The calorimeter test of the steam in the *Hyacinth* was therefore made under decidedly unfavorable conditions.

Moreover, there is a contradiction between the statement that the steam in the *Hyacinth* showed more wetness at powers between 8,000 and 10,000 H.P., and the fact that these very horsepowers are the only ones at which the *Hyacinth's* engines showed greater efficiency than those of the *Minerva*. This fact would be inexplicable if the amount of water carried over from the *Hyacinth's* boilers during the trials did, in fact, attain the proportions indicated by the calorimeter, for it is well known that, on the contrary, the efficiency of the engines very sensibly diminishes in proportion as the steam is wetter.

In short, Table XXVI proves more clearly still, if it is possible, that the quality of the steam of the *Hyacinth's* Belleville

boilers, at horsepowers of from 8,000 to 10,000, is not inferior to that of the *Minerva's* boilers. This table allows of the comparison, as regards the two vessels, of the temperature corresponding to the pressure in the valve chest of the H.P. cylinder and the temperature actually observed in this chest.

These are the figures given in lines 9, 10 and 13 of Table XXVI:

First, for the *Minerva*—

Line 9. Mean pressure by gauge on the H.P. valve chest, pounds, ... 136

Line 10. Corresponding temperature of saturated steam, degrees Fahrenheit, ... 358.5

Line 13. Mean observed temperature in H.P. valve chest, degrees Fahrenheit, ... 345

Fall of temperature = 13.5 degrees Fahrenheit.

And the following are the figures for the *Hyacinth*:

—	8,000 H.P. with exhaust.		10,000 H.P. with exhaust.
	Closed.	*Open.*	*Open.*
Line 9. Mean pressure by gauge in H.P. valve chest, pounds.....	194	192	220
Line 10. Corresponding temperature of saturated steam, degrees.....	385.1	384.3	395.4
Line 13. Mean observed temperature in H.P. valve chest, degrees.....	391.6	389.1	394.1
Excess of temperature, degrees..	6.5	4.8	...
Fall of temperature, degrees.....	...	...	1.3

Therefore, in the *Minerva*, with 8,000 H.P., the thermometer indicates a fall of temperature of 13.5 degrees, as compared with the temperature corresponding to the gauge pressure, while in the *Hyacinth*, at 10,000 H.P., this difference is only 1.3 degrees, and at 8,000 H.P. there is, on the contrary, a gain of 4.8 degrees and 6.5 degrees. The figures for the *Hyacinth*, given in this Table, undoubtedly show the steam to be perfectly dry, which is entirely in agreement with the greater efficiency of the engines at that horsepower.

Losses of Water.—The Report (page 11, line 14 *et seq.*) contains the following remarks on the question of loss of water:

"The loss of steam through leaks in boilers, steam pipes, engine stuffing boxes, &c., is given in Table XXVI, line 42. It is, of course, impossible to apportion the losses to their various causes, but the results of the Gibraltar runs lead us to look upon leaks at the boilers as being responsible for any abnormal increase in these losses. On the three progressive trials of the *Minerva*, the total losses were represented by 2.1, 3.0 and 3.7 tons of water per 1,000 H.P. per 24 hours respectively. In the *Saxonia* the figure was 2.76 tons. In the *Hyacinth* they were 5.5, 2.9 and 5.5 tons respectively, and 4.8 tons at 10,000 H.P. The irregularities here, no doubt, depend mainly on the actual tightness of the boiler joints during the runs. At 5,000 H.P. the *Hyacinth's* losses came out very well, and slightly less than those of the *Minerva* at the same power; at the other powers, both lower and higher, they were very much greater, and it was found later on, during the Gibraltar runs, that on trials of greater duration they become most serious."

Thus, during the trial at 5,000 H.P. the losses of water are a little less in the *Hyacinth* than in the *Minerva;* during the trials at 2,000 and 8,000 H.P. the losses are greater; on the runs to Gibraltar the losses are much more serious.

Attempt was made at Gibraltar, and again at Portsmouth, to discover the nature of the leaks which occasioned these losses; it does not, however, appear to have been clearly recognized at first. On the voyage out to Gibraltar a sudden slackening of speed, due to fog, had resulted in greater losses, and it was supposed that the cause might be the increase of pressure. On a special run over a free route, made during the stay at Gibraltar, the same conditions of sudden slowing down were voluntarily reproduced, with the result that the safety valves blew freely, but the tests made did not show any appreciable difference between the amount of water lost before and after the slowing down (page 18, line 50). The importance of the losses, therefore, had no visible connection either with the speed of the engines or with the pressure in the boilers, and the question

seemed involved in a certain mystery, which has been exploited to the detriment of Belleville boilers in the polemics to which the *Hyacinth* and *Minerva* trials gave rise. The question is now clearly elucidated by the experiments made with two of the *Hyacinth's* boilers at Devonport in December, 1901. The losses of water were measured with these boilers, at first in the same state in which they were at the time of the return of this cruiser from sea service. These measurements were made during six consecutive periods of twenty-four hours each. The examination of the boilers showed that the losses were due exclusively to leaks in the joints of the handhole doors of the junction boxes, the faces of which did not bear truly against each other, while the asbestos rings were of irregular thickness and defective composition. The joints were remade under more normal conditions, and in a new trial covering, like the former, a period of six times twenty-four hours, it was found that the loss had been reduced to less than one-tenth of its former amount.

The question was thus reduced to its true proportions and placed on its proper footing. We now know which were the leaky joints, and what steps are necessary to avoid such leakage. It is at present purely a question of practice, the solution of which will daily become more certain and more easy in proportion as the staff, whose attention is now awakened in the right direction, acquire more experience, and the materials prepared for the joints are better fitted for their purpose.

This elucidation, the result of the Devonport experiments, makes it easy to understand why the question of losses of water with Belleville boilers has arisen in no other navy, although every day ships of all sorts fitted with Belleville boilers accomplish, on every sea, voyages which are much longer than the run from Portsmouth to Gibraltar, thereby proving that, contrary to the opinion of the Committee (page 23, line 39), water leakage is not inherent in the very design of these boilers.

It is equally well known that it has not been judged necessary, in any navy in which Belleville boilers are used, to take any special precautions on their account, either as regards the

supply or the production of fresh water. In France, for example, the apparatus fitted for producing fresh water is calculated on the same base (4 tons of water per 24 hours per 1,000 H.P.), whether the boilers in question are Belleville, water-tube of other types, or cylindrical.

These plain facts and results of multiple and prolonged experiments, over so many fields of action, ought, in justice, to be taken into consideration. They admit of the conclusion that the losses of water experienced during the voyages to Gibraltar are due to causes practically avoidable, and that there are no grounds for drawing therefrom the general consequences the Committee have thought it their duty to deduce. The ships of all classes and all nationalities which navigate on far distant stations, the mail steamers which are daily plying on the South American lines as well as those of Australia and the Far East, undoubtedly prove that the tightness of Belleville boilers on the longest runs and the most prolonged and rapid voyages is a practical and certain fact.

Radius of Action.—This question of water loss, which, in spite of the numerous and well-known facts which we have just mentioned, is treated in the report as inherent in this design of boilers, led the Committee to conclude that the *Hyacinth's* radius of action was limited, not by her coal consumption, but by her consumption of water.

But water loss is an abnormal condition, and may be avoided; we have just demonstrated this, and there is no need to go over the ground again. Consequently in order to ascertain the true radius of action of the *Hyacinth*, or of a similar ship fitted with Belleville boilers, it is necessary to consider what this radius should be, having regard to the relationship between the amount of coal consumed and the coal capacity of the bunkers, eliminating as far as possible all factors not connected with the boilers, since it is the question of boilers alone which is here under discussion.

But let us take first the bare figures given in the report. The *Minerva*, at 7,000 H.P., ran 2,640 miles and burnt 977 tons of coal (page 17, lines 30 and 31).

The *Hyacinth* ran 1,810 miles and burnt 676 tons of coal (page 16, lines 63 and 49).

Such are the material facts.

On comparing these figures it will be seen that the *Hyacinth*, by burning the same quantity of coal as the *Minerva*, namely, 977 tons, would have run:

$$1{,}810 \times \frac{997}{676} = 2{,}616 \text{ miles.}$$

Therefore, comparing the radii of action corresponding to *the same amount of coal burnt*, the *Minerva* has an advantage of only twenty-four miles over the *Hyacinth*, that is to say, less than one per cent. This difference is almost insignificant in itself, but we shall see that if the two types of boilers had been fitted in conjunction with engines and hulls of the same efficiency, all the advantage would then have been with the *Hyacinth's* boilers, and would be proportionately greater. As a matter of fact, it is found that the efficiencies of the engines and hull of the *Hyacinth* were actually such as to diminish the radius of action of this cruiser in comparison with that of the *Minerva*.

As far as the main engines are concerned, the Report shows that the thermal efficiency was greater in the *Minerva* than in the *Hyacinth* (16.7 per cent. instead of 15.1 per cent., page 13, line 34).

This is a difference of 10 per cent. to the detriment of the *Hyacinth*, which (all other things being equal) would have had her radius of action increased in the same proportion if the same power had given the ship the same speed. But the influence of the hull here again makes itself felt, for at the same powers the *Hyacinth* developed less speed than the *Minerva*, and this difference was very considerable.

The Report (page 18, line 22 *et seq.*) gives the following important information on this subject:

In reference to the speed of the two ships, it was seen from the start, both vessels working at the same power, that the *Minerva* was the faster vessel. This result, however, to what-

ever cause it may be due, had nothing to do with the question under consideration by the Committee, and is in accordance with the contractor's trials, of which all the figures (a summary is given below) have been before the Admiralty for some time:

Hyacinth.		*Minerva.*	
H.P.	*Speed (knots).*	*H.P.*	*Speed (knots).*
2,146	12.10	4,919	17.52
7,678	17.34	8,216	19.60
10,447	19.40	9,902	20.34

These figures appear to be also in entire agreement, so far as the *Hyacinth* is concerned, with the results of the special trials of that ship made in Stokes Bay in 1900.

Therefore the *Minerva* was faster at 4,919 H.P. than the *Hyacinth* at 7,678 H.P., 17.52 knots instead of 17.34.

Is it not strictly equitable, in order to strike a fair comparison, *from the boiler point of view only*, that allowances should be made for elements whose influence is so considerable?

We do not insist on the fact that the *Hyacinth* had at her disposal on the run to Gibraltar only 968 tons of coal, while the *Minerva* had 1,016 tons in her bunkers, *i. e.*, 48 tons or 5 per cent. more (page 15, line 48).

If these two ships had been obliged to use all their coal, the *Minerva's* radius of action would then have apparently been increased by 5 per cent., and in fact, the *Minerva's* trial was closed before her coal was exhausted, but after she had already burnt 977 tons, or more coal than the *Hyacinth* had in her bunkers at the start. The conclusion drawn from the comparison of the radii of action of the two ships was, on this account, rendered misleading at the outset, for the object of the trial was to compare the powers of the boilers, and not the bunker capacities of the two ships.

In short, the gross results of the Gibraltar run, at 7,000 H.P., make out the *Hyacinth's* radius of action to be one per cent. less than the *Minerva's*, while if these results are looked at from the boiler point of view only, and allowance is made for the fact that the Belleville boilers were being used with less efficient engines,

a slower hull and a smaller bunker capacity, it is found that the advantage is very greatly in their favor.

Choking of Ferrules of the Minerva's Tubes.—The inferiority of the *Minerva's* boilers, from the point of view of radius of action, was not only due to their large coal consumption, in spite of the use of retarders, but also to the gradual choking of the ferrules of the tubes by "bird-nesting," which was in all probability encouraged by retarders being used.

Indeed, the Committee state (page 17, line 50 *et seq.*) that, in order to maintain the 7,000 H.P. on the *Minerva*, it was necessary to gradually increase the air pressure to six times its former amount (1.50 inches instead of 0.25 inch) because of the gradual choking of the ferrules, and even with that during the last seven hours of the trial the power could not be fully maintained. "The openings in the ferrules were found, on examination at Gibraltar, to be choked up across half or three-quarters of their area by a thick, hard brown slag, which also coated the surface of the tube-plates, and which was not removed until access was gained, after cooling, to the combustion chambers" (page 18, line 3).

This circumstance shortened the duration of the trial, although the *Minerva* had still thirty-nine tons of coal in her bunkers (page 17, line 58).

Chokings of a similar nature also took place on the run home, and on arrival at Portsmouth (page 23, line 51), the ferrules in all the boilers were found partially closed with "bird's-nesting" similar to that found at Gibraltar, though not so badly, on account of the lesser duration of the run.

The Committee (page 18, line 15) state their opinion that in practice the obstructions would not have appreciably delayed the ship beyond the time necessary for coaling. We may, however, be permitted to point out that the *Minerva* (page 19, line 10) arrived at Gibraltar during the night of 12th—13th July, at 12.30, and that it was not until the forenoon of the 14th (*ib.* line 13), that is more than twenty-four hours afterwards, that the boilers were sufficiently cool for men to work in the com-

bustion chambers and to *commence* to remove the deposits adhering to the tube plates and ferrules.

The time spent on cleaning these parts is not stated, but considering the adhesive nature of the deposits and the fact that they were not confined to the ferrules, but extended over the whole surface of the tube plates (page 18, line 5), the total time occupied in cooling the boilers and in cleaning was certainly much greater than that to which, in case of necessity, a ship of war can reduce the time required for coaling. In short, the obstructions were, after only 150 hours' steaming, sufficiently serious to prevent the power from being maintained, and to necessitate the abandonment of the trial while the ship still had coal available in her bunkers. These facts bring to light a serious fault as regards the *Minerva*, for, *in practice*, ships of war or commerce have frequently to make runs of much longer duration than 150 hours.

Circulation and Water Levels.—During the run home from Gibraltar a tube burst in one of the eighteen boilers of the *Hyacinth*. The Report in touching on this reiterates the apprehensions and criticisms already formulated in the Interim Report of the 19th February, 1901, on the untrustworthiness of the water-gauge indications and the defective circulation, which, in the opinion of the Committee, are the characteristic features of Belleville boilers.

For our part, we can only repeat the observations on these points we had the honor of laying before the Admiralty in our letter of the 28th March, 1901. The fact that a tube burst during the trial in question cannot nullify the results obtained every day with the innumerable Belleville boilers which are in use on every sea, beneath the flags of all maritime nations.

After all, there is no type of water-tube or cylindrical boiler in existence which, having been in use to any considerable extent and for any length of time, has not occasionally met with accidents to its tubes similar to that which happened in the *Hyacinth*.

The coming down of furnace crowns, in cylindrical boilers, is far from being an infrequent occurrence, and the consequences are

generally very serious indeed. There are, therefore, no grounds for drawing conclusions adverse to the Belleville type alone from an accident to which all types of boilers are exposed. The diversity of uses to which this boiler can be put, its well-established position and extensive use present, on the contrary, guarantees that few other designs can offer to the same decree.

Weight and Space.—The Report (page 14, line 3, *et seq.*) states that:

"The net space occupied by the main and auxiliary engines and evaporating plant in the *Hyacinth* is 28,200 cubic feet (798.5 cubic meters), and in the *Minerva* 29,240 cubic feet (828 cubic meters). Taking these figures in connection with the maximum horsepower measured on any of the Committee's trials over a period of several hours (10,180 and 8,657 H.P. respectively), they amount to 2.8 and 3.4 cubic feet (79 cubic decimal and 96 cubic decimal) in the *Hyacinth* and *Minerva* respectively.

"The weight of the boilers with funnels and water, and the whole of the boiler-room weights generally, are 453.8 and 557.4 tons in the *Hyacinth* and *Minerva* respectively. Worked out on the same H.P. as in the last paragraph, the figures come to 22.4 and 15.5 H.P. per ton of boiler weights."

The difference in weight for the complete groups of boilers is therefore 103.6 tons, *i. e.*, the *Minerva's* boilers weigh 22.8 per cent. more than those of the *Hyacinth*, and comparing the maxima powers realizable per ton of boiler weight it is seen that the *Hyacinth's* boilers can develop 44 per cent. more power than the *Minerva's*.

These differences are considerable.

The Committee are of opinion that this advantage is illusory, and that the economies realized may be more than counterbalanced by additional weight of coal and water necessary (page 14, line 18). But we have already pointed out that difficulties in regard to loss of water have arisen in no other navy, nor has it been considered necessary to provide for greater water reserve for Belleville boilers than for any other type. We have likewise shown that according to these very results obtained by the Committee, Belleville boilers possess incontestable advantages

from the point of view of efficiency, and cannot therefore themselves be the cause for increasing the coal supply. The important economies of weight and space shown by them stand to their credit, therefore, as an incontestable advantage.

In conclusion, we beg to be allowed to point out that since the preliminary Report of the Committee was published in February, 1901, a whole year has elapsed, during which time, taking the British Navy alone, about fifteen large ships, fitted with Belleville boilers, have been added to the Service, and twenty others have been kept in commission in distant seas or in active squadrons. The increasing use of these boilers appears to us not to confirm the fears of the Committee, but, on the contrary, to show that, in the British Fleet, as in all others, these boilers daily justify more and more the confidence reposed in them. And, to mention only the earlier cases in which these boilers have been fitted by the Admiralty, the cruises of the *Powerful* and the trials carried out some months back by the *Terrible*, have shown that Belleville boilers, after six years of use on board, and after long cruises in distant seas, are always capable of rendering the best and most reliable service, and have lost nothing of their power and usefulness.

We have, &c.,

DELAUNAY, BELLEVILLE & Co.

SIR EVAN MACGREGOR,
Admiralty, London, S. W.

THE BOILERS OF THE *POWERFUL*.

So much has been said and written about the Belleville boiler in the Royal Navy that an ordinary trial of the first-class cruiser *Powerful*, lately made, possesses more than usual interest. The trial was the usual service run, necessitated by the extensive alterations which have been made in the ship for the purpose of adding to her armament of 6-inch quick-firing guns, of which weapon she has now sixteen, in place of the original number of twelve. The trial in itself was without special incident in regard to the machinery, all going well from first to last. The

mean indicated horsepower was 23,508, a maximum of 24,866 being reached. The mean speed was 21.2 knots. The amount of water lost was inconsiderable—about 3 tons. The results, though not at all surprising, are very good. In regard to the speed it must be remembered that the displacement of the ship has been increased by the addition to her armament. The maximum power was practically that originally estimated in the design, or close upon 25,000 indicated horsepower.

The special interest of the trial arises from the fact that the *Powerful* was the first large vessel of the Royal Navy to be fitted with water-tube boilers, and also because she and her sister-cruiser, the *Terrible*, have been the best-abused ships in the fleet. The strictures passed upon her earlier performances were not altogether without foundation; or, at any rate, were excusable on the part of those not engineers, and therefore unacquainted with the difficulties that beset the introduction of a radical alteration in mechanical design. The *Powerful* was commissioned in June, 1897—just five years ago. Her steam trials passed off satisfactorily; but shortly after, during maneuvers, the Belleville boilers lost considerable quantities of water. This was a serious defect; but improvement was made, and the ship was despatched to the China Station. On the voyage out there was also abnormal loss of water, though not so great as on the trials. The difficulty was emphasized by the evaporators going wrong. There was also trouble with the bearings of the main engines. This difficulty was also overcome, but not without considerable labor and anxiety. It had nothing to do with the boiler system, though some critics took occasion to attribute every mishap that occurred on board to the new system of steam generation.

The abnormal loss of water naturally led to an excessive fuel consumption, but after the *Powerful* arrived on the station the engineering staff had a better opportunity of studying the ship's machinery. By eliminating first one source of loss and then another, the consumption of coal, due to preventable losses, was reduced more than 50 per cent. Ultimately the consumption of water was brought down to as little as that which is normal with ships of the Royal Navy, having either boilers of the ordi-

nary cylindrical type or of any other description. At times the figure has been considerably below the average. The *Powerful's* boilers are those originally placed in her when she was built, in 1895. A few tubes have been taken out solely in order to cut them open and see the result of working. Two tubes have also been replaced owing to an accidental salting up of the boilers due to a leaky condenser. Otherwise the same tubes are in the boilers now that were originally fitted, including other tubes that were incrusted with salt at the same time, and which were cleaned out. So far as can be judged, all these tubes are in as good condition as at first, though naturally some result of wear must be expected.

The moral is plainly to be read. If one ship, under by no means favorable conditions, and with a very bad start, can work with water-tube boilers for an extended period, other ships, under similar conditions, can perform equally well. These conditions are the result of experience, coupled with engineering skill, and not a little hard work. Moreover, the experience with the *Powerful* is not unique; and it may be said in passing that great credit is due to the engineering staff of each of His Majesty's ships which have overcome the difficulties by which the introduction of this new system of steam generation was undoubtedly beset. It is worthy of note that at the same time that the machinery of the *Powerful* was being constructed at Barrow there were being completed the engines and boilers of H. M. S. *Majestic*. This battleship had cylindrical boilers, which were to be pressed to 150 pounds to the square inch, whilst the boiler pressure with the *Powerful* was 260 pounds to the square inch. Succeeding Belleville boilers were worked at 300 pounds to the square inch. It had taken about seventy years to work up from the low steam pressure, originally used with marine engines, to the 150 pounds of the *Majestic's* cylindrical boilers; but with the water-tube boiler this latter pressure was doubled practically at one step. There was, of course, no question that the water-tube boiler would safely stand the stress, but engineers will appreciate the many subsidiary difficulties, outside the boilers themselves, that have arisen through this great increase of pressure, and the

additional watchfulness and anxiety it entailed upon the engineering staff.

Although the Belleville boilers have undoubtedly done well in the *Powerful*, it does not, of course, at all follow that they are the best type of water-tube boiler. Their performance is, however, an answer to much of the captious and often interested criticism which has been directed against the Admiralty authorities for taking a decided step forward in the practice of naval engineering. Our readers will remember that in our own comments upon the introduction of this type of boiler into the Navy we have always held in reserve any opinion on the question of durability; and it would seem from the experience with the *Powerful* that this is not likely to be a weak point in water-tube boiler practice.—London "Engineering."

COMBINATION BOILER SYSTEMS.

The type of boilers for the new English armored cruisers has now been decided upon, subject to arrangement with the contractors as to price, and for the changes in the machinery rendered necessary by the reduction in the steam pressure. The various firms are now preparing revised tenders. The original tenders included prices for different boiler systems, including a set for an installation of cylindrical boilers, equal to two-fifths of the power, and various water-tube boilers for the other three-fifths; but the combination now decided upon is one-fifth of tank boilers and four-fifths of water-tube boilers. The steam pressure at all the boilers is to be 210 pounds and the same at the engines; while formerly the boiler pressure was to be 260 or 270 pounds and 250 pounds at the engines. This necessitates a larger piston area in each cylinder to ensure the same power for the less pressure; and thus the machinery must be considerably modified.

There were six cruisers ordered. The *Antrim*, allotted to John Brown & Co., Ltd., is to have Yarrow boilers for 17,600 I.H.P., and cylindrical boilers for 4,400 I.H.P., fitted on the Howden system of forced draft with closed ash pit. The others of

the six cruisers will have their tank boilers similarly equipped. One of these is the *Roxburgh*, to be built and engined by the London & Glasgow Co.; but in this case the Dürr water-tube boiler to be fitted. Beardmore & Co.'s cruiser, the *Carnarvon*, will have the Niclausse boiler for four-fifths of the power and ordinary cylindrical boilers for the other fifth. Scott & Co.'s cruiser, the *Argyll*, is to have Babcock and Wilcox boilers for 17,600 I.H.P. and ordinary tank boilers for the rest. Thus all of the four Clyde-built cruisers will have distinctive types of boilers.

Of the other two cruisers, that built by Sir W. G. Armstrong, Whitworth & Co., at Elswick, and engined by Hawthorn, Leslie & Co. (the *Hampshire*), will have Yarrow large-tube boilers; but in the case of the cylindrical boilers Howden's system will not be adopted. In the sixth ship, the *Devonshire*, building at Chatham, and to be engined by the Thames Iron Works Co., the Niclausse boiler will be fitted, but the cylindrical boilers will be of the Howden type. In two of the ships Yarrow boilers will be used—in the Brown and Elswick ships; in two others—Beardmore's and Chatham vessels—the Niclausse boiler will be used; in one—the London & Glasgow—the Dürr will be adopted, and in the Scott vessel the Babcock. These types of boilers have all been tried in the service. The Yarrow large-tube boiler is fitted in a third-class cruiser recently reboilered at Palmer's. As a small-tube boiler it has been adopted, both separately and in combination, by several European powers, and it is being fitted to two swift Chilean battleships now being built in this country. The Niclausse boiler has been applied in two sloops, and is being constructed for two vessels of the County class—*Suffolk* and the *Berwick*—the latter building at Beardmore's.

The Dürr boiler has also been fitted to an old third-class cruiser, and is to be fitted to a second-class cruiser, the *Encounter*, of 12,500 I.H.P. The Babcock boiler is now the most widely adopted type, excepting the Belleville. Harland & Wolff are putting it in the battleship *Queen*, of 18,000 I.H.P.; Hawthorn, Leslie & Co. into the armored cruiser *Cornwall*, of 22,000 I.H.P., and all three new battleships of the *King*

Edward VII type are being fitted with this system. In one instance it is in combination with cylindrical boilers. The idea of having one-fifth of the steam power derived from cylindrical boilers is to enable the ship to steam at ordinary cruising rates without resorting to the use of the water-tube generators, and that the new vessels should be able to make 15 knots under these conditions. When higher powers are required, the water-tube boilers will come into use, and they can develop full pressure within a few minutes of fires being lighted. — "Marine Review."

THE DOCKING OF BATTLESHIPS.

Paper read at the fifth annual meeting of the Society of Naval Architects of Japan, and translated by Mr. M. Kondo, I. J. N.

By M. Asaoka, Imperial Japanese Navy.

We are now able to put before our readers a translation of the paper read last autumn before the Japanese Society of Naval Architects, by Commander Asaoka, of the Japanese Admiralty. It has been translated for us by Captain M. Kondo, also a Chief Constructor in the Japanese Admiralty. The chief interest in the paper will be found to lie in the comparison of the methods of applying the shores employed in Japan with those employed in our own dockyards, and in the results of observations made upon the deflection of ships during docking. To English readers the superiority claimed for the Japanese methods will seem a little daring: to justify the claim some knowledge of deflection experienced by ships docked according to English methods would appear to be necessary. We cannot help thinking that more is known on this point than would appear from the paper; but until some one who may have the information at home is prepared to publish it, Mr. Asaoka must be allowed to have presented a *prima facie* case for fuller investigation.

The docking of a heavy ship always involves so much care and so many precautions that it would almost take a treatise to fully discuss the question. I only intend to give here the out-

line description of the different operations to be gone through in docking modern battleships.

Before doing so, however, it is as well to consider what are the weights of different items that enter into the construction and equipment of a battleship and their dispositions.

The following are the percentage ratios of the principal items:

Hull and fittings,	38.1
Protection,	31.5
Armament,	11.1
Machinery,	9.9
Coal,	4.8
Equipment,	4.6
	100

Thus it will be seen that only 38.1 per cent. of the total displacement of the ship is the weight of the hull and fittings, while 61.9 per cent. is the sum of all the weights carried by the hull, or "load." In other words, the hull has to carry nearly twice its own weight, and, moreover, support it safely in all kinds of wind and weather, sometimes even losing the benefit of the surrounding water, being left dry in dock. These weights, furthermore, are very unevenly distributed over the length of the ship, reaching 80 tons per foot length under the heavy-gun stations, and over 60 tons in the less-heavily laden portions amidships. It is not unusual to find a pressure of from 50 to 60 tons per square foot on the keel blocks. Now the ship's hull, which carries all these weights, is nothing but a large hollow girder composed of thin steel plating. While the ship floats in water, the pressure of water distributed over the whole of the bottom supports the weights of the vessel; but in a drydock more than half the weight is borne by the keel blocks. These blocks, though strong enough to support the weight, give no help in preventing the sides of the ship—75 to 76 feet in width—from sagging. This is the reason why it is necessary to provide shoring ribbands. In fact, one of the difficulties the constructors have to contend with is to give efficient support to the ship's

sides, and avoid injurious deformations of the shape of the hull. Now as to the actual *modus operandi*, there is not much difference between the practices of the British naval dockyards at Portsmouth and Chatham and those that obtain in our naval yards at Yokosuka and Kure.

In my opinion, however, our practices are more perfect than any other I know, and I shall now proceed to describe several operations step by step, leaving out those parts that are common to all docking. When a battleship is about to be docked the positions of the barbettes and principal bulkheads are noted, and keel blocks prepared and placed in position. Special blocks and shores are also prepared for the raised portions of the keel at the ends of the vessel.

Coal, ammunition, boiler water, provisions and all the other movable weights are taken out of the ship; and if there is excessive want of trim it is rectified by admitting water into the trimming tanks. About twenty internal shores, about 9½ inches square, are applied in the double bottom, under the principal bulkheads, to protect the floor plates and prevent them from buckling. (This is not done in England.) Floating wooden fenders are prepared and placed at the side of the dock entrance to prevent the ship's sides from touching the stone wall.

When the ship assumes her assigned position in dock the caisson is sunk and the water is pumped out in the usual manner, until the keel just touches the block. The first tier of shores is then applied. The second tier is put in next, the time taken by the two operations being 10 and 45 minutes, respectively.

Next the verticals are applied, pumping being stopped while there is still some 19 feet or 20 feet of water. Four gangs of divers are employed for setting up the wedges under water, the time taken being about five hours, and the number of verticals from 50 to 60. In England each vertical is applied only when the altar on which it is to rest appears above water, and there is only 7 feet or 8 feet of water under keel at stern.

The blocks and shores for the raised portions of the keel at bow and stern are now applied, likewise by divers; this absorbs from 40 to 50 minutes. (In the English practice this is also left

till the dock is practically dry.) The shoring of the third row is now proceeded with, and requires another 40 or 50 minutes.

We now apply the bilge blocks, five or six in number, on each side. These are prepared beforehand, and placed on each side of the dock bottom, some distance away, on each side of the place they ultimately occupy. These are applied when their upper edges begin to appear above water. This takes another 30 or 40 minutes. (This is entirely dispensed with in England.) The dock is now pumped out dry, and the fourth, fifth, sixth and seventh rows of shores are applied, taking, on the average, about an hour and three-quarters. These shores are 130 or 140 in number on each side.

At Yokosuka the stay in dock ranged from six to ten days, and at Kure five or six days. Our ships remained in dock in England from thirteen to fifteen days.

At Portsmouth the blocks were 15 inches wide, with 27 inches space between them, and at Chatham they were 13 inches and 20 inches, respectively. In our yards these figures are 12 inches and 20 inches, respectively, with additional blocks under barbettes, giving only a space of 4 inches between them at these places. (In England these additional blocks were never used, except when the *Asahi* was docked at Portsmouth, when a few intermediate blocks were placed by the Clydebank Company, at our request.)

As the keel rests on the blocks and the water decreases it is the natural tendency for the sides of the ship to sag, and there is an appreciable drop in many cases. This is greatest just before the application of the verticals, and also when the ship finally rests on the blocks.

Of course, the amount varies in different cases, but it ranges between $\frac{1}{8}$ inch and $\frac{1}{4}$ inch. This latter is only about one two-thousandth part of the full depth of about 45 feet. The hull generally recovers its original form when the ship is again waterborne. There is, however, not the slightest doubt that this strain cannot be without injury to the hull, and care must be taken that the ship does not stay in dock even a day longer than is absolutely necessary.

TABLE I.—DOCKING PARTICULARS

Name of dockyard	Portsmouth	Portsmouth	Chatham	Yokosuka
ship	*Asahi*	*Azahi*	*Hatsuse*	*Fuji*
Depth of water over sill	30 ft. 3 in.	30 ft. 6 in.	32 ft. 6 in.	28 ft. 7 in.
Draught of water, forward	24 7	24 0	21 10	24 6
aft	25 6	24 9	26 0	24 5
Ditto, when verticals were applied	8 2	8 2	9 0	19 6
Ditto, when the blocks for raised portions at fore-and-aft ends were applied	0	0	0	19 6
Ditto, when water was admitted previous to undocking	...	...	...	19
Width of keel blocks and space between	15 in. × 27 in.	15 in. × 27 in.	13 in. × 20 in.	12 in. × 20 in.*
Number of shores, one side, 1st row	14	15	13	14
Number of shores, one side, 2d row	13	13	13	13
Number of shores, one side, 3d row	16	14	14	10
Number of shores, one side, 4th row	14	13	...	...
Number of shores, one side, 5th row	...	...	...	...
Number of verticals, one side	28	28	28	27
Additional shores at fore end	2	2	3	5
blocks at fore end	4	8	0	3
shores at after end	3	3	0	6
blocks at after end	0	0	0	1
Number of buttresses, one side	0	0	0	4
bottom shores, one side	...	...	53	190
Date of docking	11 a.m. 1st day	5·50 p.m. 1st day	1·30 p.m. 1st day	4 p.m. 1st day
When caisson was set	11·45 " "	6·30 " "	2 27 " "	4·20 " "
pumping was started	11·50 " "	8·50 a m. 2d day	4 " "	4·40 " "
keel sat on blocks	2·9 p.m. "	10·15 " "	4·13 " "	5 " "
When horizontal shores were set up, 1st row	2·20 " "	10·30 " "	4·35 " "	5·15 " "
When horizontal shores were set up, 2d row	3·50 " "	9 " 4th day	10 a m. 2d day	5 45 " "
When horizontal shores were set up, 3d row	1·35 " 2d day	1·30 p m. "	11·55 " "	6 " "
When horizontal shores were set up, 4th row	3 " "	2·35 " "	...	...
When horizontal shores were set up, 5th row	...	...	...	...
When pumping was stopped for applying verticals	4·50 p.m. 1st day	10 a.m. 4th day	7 25 p m. 1st day	5·50 p.m. 1st day
Time taken in applying verticals	2 hr. 30 min.	2 hr. 5 min.	3 hr. 40 min.	5 hr. 20 min. by divers
blocks for raised portions at ends	30 min.	35 min.	...	4 hr. 20 min. by divers
When pumping was resumed	11·30 a.m. 2d day	...	10 a.m. 2d day	1·30 p m. 2d day
dock was pumped out	3·10 p.m. "	1·20 p.m. 4th day	1 p.m. "	8·50 " "
Time taken in applying bilge blocks	...	...	...	40 min.
Time taken in applying bottom shores	1 hr.	2 hr. 10 min.	3 hr. 35 min.	1 hr. 40 min.
When painting was begun	8 a.m. 7th day	1 p.m. 8th day	7th day	6·30 p.m. 4th day
finished	4 p.m. 12th day	10·30 a.m. 11th day	12th "	3 " 5th "
When all work inside dock was finished	" "	10 a.m. 12th day	12th "	3 " "
When water was admitted into dock	11·45 a.m. 13th day	6·18 a.m. 13th day	10·15 a.m. 14th day	4 " "
When admission of water was suspended	...	...	...	6 " "
When caisson was opened	2·30 p.m. 13th day	8·20 a.m. 13th day	8 a m. 15th day	6·40 a.m. 6th day
When ship was undocked	3·45 p.m 13th day	9·20 a.m. 13th day	8·15 " "	7·20 a.m 6th day

*4 in. in some places.

FOR CERTAIN BATTLESHIPS.

Yokosuka *Yoshima*	Yokosuka *Hatsuse*	Yokosuka *Asahi*	Kure *Shikishima*	Kure *Fuji*	Kure *Yashima*
28 ft. 3 in.	28 ft. 3 in.	28 ft. 6 in.	32 ft. 2 in.	34 ft 6 in.	32 ft. 8 in.
24 6	23 8	24 0	24 3	24 0	24 2
25 2	25 1	24 9	25 5	24 8	24 6.3
20	19 6	19 6	20 5	20 5	20 5
20	19 6	19 6	20 5	20 5	24 5
20	19 6	18 0	19 0	18 0	19 0
12 in. × 20 in. *	12 in. × 20 in.*	12 in. × 20 in.*	12 in × 20 in.*	12 in × 20 in.	12 in. × 20 in.†
15	15	16	17	15	15
14	15	14	15	14	14
11	13	14	17	15	15
...	...	...	15	15	14
...	...	...	11	9	12
27	29	28	27 and 6	27 and 5	27 and 9
7	4	4	} 19	21	10
9	6	6	}		
6	...	...	} 8	38	10
1	2	4	}		
4	5	5	7	5	5
135	138	140	140	120	112
6·10 a.m 1st day	5·15 a.m. 1st day	5·20 a.m. 1st day	6·10 a.m. 1st day	8·30 a.m 1st day	7 a.m. 1st day
7 " "	5·30 " "	7 " "	7·10 a.m. "	8·55 " "	7·14 " "
7·5 " "	5·40 " "	7·30 " "	" " "	" " "	" " "
7·40 " "	6 10 " "	8 " "	9·55 " "	11·11 " "	8·43 " "
7·50 " "	6·20 " "	8·15 " "	10·7 " "	11·15 " "	8·48 " "
9·20 " "	7 " "	9 " "	10·13 " "	11·30 " "	8·54 " "
9·30 " "	8 " "	10 " "	9·45 p.m. "	9·50 p.m. "	2·17 p.m. "
...	...	...	11·20 " "		3·58 " "
...	...	..	5·20 a.m. 2d day	11·20 p.m. "	6 10 " "
				...	
9·15 a.m. 1st day	6·50 a.m. 1st day	9 a.m 1st day	10·40 a m. 1st day	12·10 p.m. "	9·50 a.m. "
5 hr. 45 min. by divers	5 hr. 40 min. by divers	6 hr. by divers	9 hr. 10 min. by divers ‡	8 hr. 45 min. by divers ‖	4 hr. 5 min. by divers §
1 hr. 20 min. by divers	50 min. by divers	2 hr. "	1 hr. 30 min.	5 hr. 45 min.	4 hr. 57 min.
7 a.m. 2d day	5·50 a.m. 2d day	6·30 a.m. 2d day	9·30 p.m. 1st day	9·48 p.m. 1st day	2·5 p.m. 1st day
12·40 p.m. 2d day	11 " "	12 noon "	6·15 a.m. 2d day	1·30 a.m. 2d day	8 " "
40 min.	20 min.	30 min.	30 min.	31 min.	30 min.
2 hr. 40 min.	1 hr. 40 min.	1 hr.	1 hr. 15 min.	1 hr. 28 min.	1 hr. 5 min.
6 a.m. 3d day	7 a.m. 3d day	8 a.m. 4th day	12·15 p.m. 3d day	7·15 a.m. 3d day	12·7 p.m. 2d day
2 p.m. 4th "	10 a.m. 5th day	9 " 6th "	4·20 p.m. 5th day	3·30 p.m. 6th day	10 a.m. 5th "
2 " "	1 p.m. "	11 " "	4·20 p.m. "	3·30 " "	10 " "
2·50 " "	1·20 " "	11 " "	6·45 a.m. 6th day	4 " "	12·55 p.m. "
4·30 " "	3·40 " "	1·10 p.m. "	8·45 " "	4·30 " "	6·57 a.m. 6th day
11·20 a.m. 7th day	6·40 a.m. 6th day	12·40 p.m. 10th day	9·25 " "	10·50 a.m. 7th day	9·30 " "
12·20 p.m. 7th day	8 " "	1·30 p.m. 10th day	10·8 " "	12·30 p.m. 7th day	10·10 " "

† Continuous in some places.

‡ 2 hrs. 45 min. for extra 5 verticals.

‖ 50 min. for extra 5 verticals.

§ 2 hrs. for extra 9 verticals.

In England this sag was not measured,* and I cannot say what the amount was, but that the long stay involves some danger to the ship can be shown by the instances of the *Shikishima* and the *Asahi;* and in my opinion it is advisable that, as far as the condition of the ship's bottom permits, the docking of heavy ships should be as seldom and as short in stay as possible.

We adopt three separate methods in measuring the sag, viz:

1. A set of battens on the dock side, to take sight on a certain object or spot on the ship's side.

2. Sight lines taken along spots on three battens placed transversely nearly amidships on the main deck.

3. Three horizontal battens at fore, middle and after parts of the keel blocks. The measurements are taken (1), when the keel first rests on the blocks; (2), when the pumping is stopped for applying the verticals; (3), when the dock is quite dry; and (4), when water is again admitted and attains the level of 19 feet to 20 feet.

The keel blocks are of Kashi in our yards, and are composed of English oak and cast iron in the British naval yards. These are, of course, exceedingly hard, but at Yokosuka we noticed the top of the blocks to fall $\frac{3}{4}$ inch to $1\frac{1}{2}$ inches.

At Portsmouth the top of the blocks had a round up of $\frac{1}{2}$ inch. The writer once used a thin piece of soft pine, about 3 inches thick, over the top of the blocks, when the Russian armor-clad *Admiral Nachimoff* was docked. The compositions applied are two coats of anti-corrosive and one of anti-fouling, with an occasional addition of anti-fouling boot topping.

The parts over the keel blocks cannot be painted, but all the other parts are coated with compositions, shores being temporarily removed to paint the surface under them and a piece of thick paper inserted to protect the paint when the shores are replaced. All the prominent hollows are filled in with putty or cement, and the surface made smooth. The cost of coating the bottom, including labor, is from 10d. to 1s. per square yard. Previous

* When the *Shikishima* was docked, we did measure the sag, and found the amount to be about $\frac{1}{4}$ inch on the breach of about 63 feet. We used the second of the methods mentioned above.

to admitting water into the dock, the fourth and all lower tiers of shores are removed. At Portsmouth these shores were left as they were, with the result that, as they began to float, they were caught by the bilge keels and damaged the paint considerably; an effect which is avoided by the Japanese method.

TABLE II.—OBSERVED STRAINS OF SHIPS.

Name of dockyard	Yokosuka.	Yokosuka.	Yokosuka.	Yokosuka.	Kure.
ship.....	*Fuji.*	*Yashima.*	*Hatsuse.*	*Asahi.*	*Shikishima.*
When keel sat on blocks.....	...	...	...	...	...
When water was pumped to 19 ft. 6 in. draught, ins. *a*	1 1/16	9/16	1 1/16	1 3/16	...
When water was pumped to 19 ft. 6 in. draught, ins. *b*	1/2	3/8	1/2	3/4	...
When water was pumped to 19 ft. 6 in. draught, ins. *c*	5/16	1/16	1/16	1/16	...
When dock was pumped out, ins. *a*	1 5/16	1 5/16	1 1/2	1 1/16	3/8
When dock was pumped out, ins. *b*	1	1 1/8	1 1/4	1 1/8	...
When dock was pumped out, ins. *c*	1/8	1/2	1/4	1/16	...
When water was admitted to 19 ft. draught, ins. *a*	1	1/2	1 1/2	1 1/16	...
When water was admitted to 19 ft. draught, ins. *b*	7/8	1 1/16	7/8	1 1/8	...
When water was admitted to 19 ft. draught, ins. *c*	1/8	1/2	1/4	1/4	...

a. Drop of a spot on ship's side with respect to dock side.
b. Drop of keel.
c. Drop of ship's sides with respect to middle.

It may be objected to by some that it is injurious to remove the shores beforehand; but it is only about 20 minutes before the ship receives substantial support from the water, and it is better to risk leaving the bottom unsupported for a short time, and secure that the paint remains in good condition. It takes one to two hours to apply these shores in the first instance, the bottom being only partially supported during all that time, and 20 minutes, more or less, just before being undocked does not matter much after all. The particulars relating to the docking are given in Tables I and II.—London "Engineering."

MISCELLANEOUS NOTES.

THE *HYACINTH* AND THE *MINERVA*.

The cruisers *Hyacinth* and *Minerva* are to be fitted shortly with differently-pitched propellers, with which a further series of trials will be made.

THE DUTCH MINISTER OF MARINE, in reply to a recent question asked in the States-General as to what form of boiler he proposed to adopt for their new ships, stated that he intended to adhere to the boilers of the Yarrow type, which had many advantages over all others, the disadvantages having gradually diminished or disappeared by experience.

THE ADMIRALTY has adopted a new regulation in reference to steam trials of ships in commission. When the water-tube boiler was adopted it was decided that the full-power contract trial should last for eight instead of four hours, and the continuous steaming-power trial (75 per cent. of the total power) for thirty instead of eight hours. A corresponding change has been made in connection with service runs. Once a quarter every ship in commission will steam for eight instead of four hours at full speed, and for the remainder of the twenty-four hours at continuous steaming power. Cruising will be done at about one-fifth power, "ordinary" service will be at two-fifths power, proceeding with "despatch" at three-fifths, with the "utmost despatch" at four-fifths, and on "emergency duty" at full speed.

PNEUMATIC TOOLS IN THE NAVY.—It has been known for some time that experiments have been proceeding with a view to the adoption of pneumatic tools on British men-of-war. We are now in a position to announce that the order for the first complete installation for this purpose has been entrusted to the International Pneumatic Tool Company of London, whose works are at Chippenham. The plant is shortly to be placed on board H. M. S. *Assistance*, which it is intended shall act as a workshop to the fleet in time of peace, and it is being fitted up with this object. The installation, so we gather, is to consist of a motor-driven air compressor, drills and hammers of various types, air receiver, piping, &c., all designed for the special conditions under which they will have to work, and so arranged that they will be available for use within a few moments of switching on the motor. The whole idea reflects great credit on the Admiralty, for such a repair ship as it is evidently intended to make the *Assistance*

should prove of immense value, particularly during maneuvers. The addition of a pneumatic tool installation should greatly add to its effectiveness, for it will enable work to be carried out in places otherwise inaccessible. There is every indication that pneumatic tools have a wide field of usefulness on board ship—not only on warships, both in times of peace and war, but also in the mercantile marine.—London "Engineer."

TESTING TORPEDO-BOAT DESTROYERS.—In order to test the strength of torpedo-boat destroyers the British Admiralty has ordered a remarkable experiment to be made at the Portsmouth Dockyard. One of the drydocks is being especially prepared for the destroyer *Wolf*, where she will be subjected to a series of tests which will include hogging and sagging strains. At first she will be sagged by being hung by the head and stern from two platforms having no support beneath. The middle will then be hogged—that is, she will be balanced across a pile of timber so that the full strain of the unsupported fore-and-aft parts will be thrown on the center of the vessel. The experiments will prove whether a destroyer's hull is so weak, as was suggested in the case of the *Cobra*, that the back breaks when a wave lifts her amidships, or a sea lifts her in such a manner that the wave is hollow beneath her middle.—"Marine Review."

AFTER THE RECENT EXPERIMENTS carried out with the torpedo-boat destroyer *Star* fitted with bilge keels, the Admiralty decided that bilge keels shall be fitted to all vessels of this class. The experiments demonstrated that the rolling tendency of destroyers may be diminished without an appreciable diminution of speed.

AN OLD BATTLESHIP is to be used at Devonport, England, so that engineers and stokers may receive instruction respecting the types of water-tube boilers. In the vessel's stokehold will be placed a boiler of each of the following types: Yarrow, Dürr, Babcock and Wilcox, Belleville and Niclausse types.—London "Engineer."

THE GERMAN EMPEROR has ordered that all the vessels of the Imperial Navy be exclusively fitted with Slaby-Arco instruments for wireless telegraphy; and he has also expressed the desire that German steamboat companies should employ the same instruments. In this connection the "Matin" recalls the circumstance that, during Prince Henry's return voyage from America, a few hours after leaving New York, the *Deutschland* signalled the lightship *Nantucket*, which cut off communication on finding that it was the *Deutschland*, with the Slaby-Arco instruments, which signalled.

THE TERRIBLE'S recent coaling record works out at just over 272 tons an hour. She took over 2,500 tons in 9½ hours—a larger quantity than has ever been handled before—and the enormous total makes the record even better than the figures look. The records now run: (1) *Terrible*, average 272 tons; (2) *Prince George*, average 208 tons; (3) *Majestic*, average 203 tons. The *Terrible's* record has, we believe, been beaten in some of the German coaling competitions; but the amounts handled are, of course, considerably less. The first few hours of coaling usually bring the coal in merrily; it is the "last few tons" that tend to lower the average.—London "Engineer."

SOME FRENCH NAVAL EXPERTS are reported to have evolved a process whereby petroleum is made semi-solid, mixed with coal dust, and pressed into briquettes. It is claimed that a splendid fuel is thus produced, and among its advantages are economy and the absence of dust or ashes. One brick, it is said, generates the heat of four times its weight of anthracite coal.

SHIPS.

The Naval Appropriation Bill, as passed, provides for the increase of the Navy as follows:

"That for the purpose of further increasing the naval establishment of the United States the President is hereby authorized to have constructed by contract two first-class battleships carrying the heaviest armor and most powerful ordnance for vessels of their class upon a trial displacement of not more than 16,000 tons, and to have the highest practicable speed and great radius of action, and to cost, exclusive of armor and armament, not exceeding $4,212,000 each; two first-class armored cruisers of not more than 14,500 tons trial displacement, carrying the heaviest armor and most powerful armament for vessels of their class, and to have the highest practicable speed and great radius of action, and to cost, exclusive of armor and armament, not exceeding $4,659,000 each; two gunboats of about 1,000 tons trial displacement, to cost, when built, exclusive of armament, not exceeding $382,000 each; and the contract for the construction of each of said vessels shall be awarded, by the Secretary of the Navy, to the lowest best responsible bidder, having in view the best results and most expeditious delivery; and in the construction of all of said vessels the provisions of the act of August 3, 1886, entitled 'An act to increase the naval establishment,' as to materials for said vessels, their engines, boilers and machinery, the contracts under which they are built, the notice of any proposals for the same, the plans, drawings, specifications therefor, and the method of executing said contract, shall be observed and followed; and, subject to the provisions of this act, all said vessels shall be built in compliance with the terms of said act, and in all their parts shall be of domestic machinery; and the steel material shall be of domestic manufacture and of the quality and characteristics best adapted to the various purposes for which it

may be used, in accordance with the specifications approved by the Secretary of the Navy; and not more than two of the six battleships, armored cruisers and gunboats provided for in this act shall be built by one contracting party.

"One battleship or one armored cruiser herein provided for shall be built on or near the coast of the Pacific Ocean or the waters connecting therewith, but if it shall appear to the satisfaction of the President from the bidding for such contracts that said vessel cannot be constructed on or near the coast of the Pacific Ocean at a cost not exceeding four per centum above the lowest accepted bid for the corresponding vessel provided for in this act, he shall authorize the construction of said vessel elsewhere in the United States, subject to the limitations as to cost hereinbefore provided: *Provided*, That the Secretary of the Navy shall build one of the battleships authorized by this act in such navy yard as he may designate: *Provided further*, That the Secretary of the Navy shall build all the vessels herein authorized in such navy yards as he may designate, should it reasonably appear that the persons, firms or corporations or the agents thereof, bidding for the construction of any of said vessels, have entered into any combination, agreement, or understanding, the effect, object or purpose of which is to deprive the Government of fair, open and unrestricted competition in letting contracts for the construction of any of said vessels.

"The Secretary of the Navy is hereby instructed to keep an accurate account of the cost of inspection and construction of vessels provided for in this act, whether built in government yards or by contract, and report thereon to Congress at each session, the progress of work and cost thereof, including the inspection of all the material going into the construction of said vessels, and, upon the completion thereof, to report a full and detailed statement, showing the relative cost of inspection and construction in government yards and by contract.

"And for the purpose of preparing and equipping such navy yard or navy yards as may be so designated for the construction of any such vessel, the sum of $175,000, or so much thereof as may be necessary, is hereby appropriated for each of the navy

yards in which the Secretary of the Navy may direct any such vessels to be built; and the Senate agree to the same."

In addition, two tugs to cost $70,000 each were provided for. These tugs will be built, one at the Boston yard and one at Mare Island.

The battleships are to be known as the *Connecticut* and the *Louisiana;* the armored cruisers as the *Tennessee* and the *Washington;* and the gunboats as the *Paducah* and the *Dubuque.* The *Connecticut* will be built at the New York navy yard.

BATTLESHIPS "CONNECTICUT" (No. 18) AND "LOUISIANA" (No. 19) FOR THE UNITED STATES NAVY.

The principal dimensions are:

Length on load-water line, feet	450
between perpendiculars, feet	450
over all, feet and inches	456– 4
Breadth, extreme, to outside of plating, feet and inches	76– 8
armor, feet and inches	76–10
Trial displacement, about, tons	16,000
draught, to bottom of keel, feet and inches	24 -6
speed, knots	18

The main battery will consist of four 12-inch breech-loading rifles; eight 8-inch breech-loading rifles; twelve 7-inch breech-loading rifles.

The secondary battery will have twenty 3-inch (14-pounders) rapid-fire guns of 50 calibers in length; twelve 3-pounder semi-automatic guns; six 1-pounder automatic guns; two 1-pounder semi-automatic guns; two 3-inch field pieces; two machine guns of .30 caliber; six automatic guns of .30 caliber.

The propelling engines will be right-and-left, placed in water-tight compartments and separated by a middle-line bulkhead. They will be of the vertical, inverted-cylinder, direct-acting, triple-expansion type, each with a high-pressure cylinder 32½ inches, one intermediate-pressure cylinder 53 inches, and two low-pressure cylinders 61 inches in diameter. The stroke is 48 inches, designed to develop a total of 16,500 indicated horse-power at 120 revolutions per minute, with a steam pressure of

250 pounds at the high-pressure cylinder. All cylinders are steam-jacketed. The order of cylinders, beginning forward, will be forward low, high, intermediate, and after low.

The forward low and the high-pressure cranks are opposite; also the intermediate and after low-pressure cranks, the second pair being at right angles to the first.

The sequence of cranks will then be high pressure, intermediate pressure, forward low, and after low pressure.

Going ahead the engines will turn inboard. For aid in balancing the reciprocating parts of the high and forward low, and of the intermediate and after low-pressure cylinders, the high and intermediate-pressure piston rods and connecting rods are increased in weight by reducing the diameters of the axial holes.

The main valves are of the piston type, one 17½ inches in diameter for the high-pressure cylinder and two of 19 inches diameter for each of the other cylinders. They are made of hollow cast-steel heads, riveted to steel tubes. The packing rings will be so constructed that they will allow of contraction, but not of expansion. Each piston valve will have one balance piston.

The link motion will be of the Stephenson type, with double-bar links and open rods.

Each reversing arm will be fitted with independent adjustment for the cut-off in its own cylinder. The ahead eccentrics will be adjustable, and the valve gear will be interchangeable.

The reversing engine consists of a steam cylinder 13 inches in diameter, and an oil-controlling cylinder 7 inches in diameter. The piston valves of the steam and oil cylinders will be worked simultaneously through a system of floating levers.

For reversing by hand a pump will be connected to the oil-cylinder valve chest.

Live steam will be admitted to the receivers, controlled by hand wheels at the working platform.

The forward low and high-pressure cylinders are bolted together by a number of fitted bolts, the intermediate and after low-pressure cylinders are similarly fitted. These four main

cylinders are supported by twelve finished, forged-steel columns, trussed athwartship by diagonal steel braces of a rectangular section, and with horizontal tie rods at the middle of each pair.

Fore-and-aft horizontal tie rods will be fitted on each side, between the three pairs of columns of the two forward cylinders, and again repeated for the two after cylinders. The top and middle of the central columns of each set of three pairs will be braced diagonally, in a fore-and-aft direction. These central columns will also be braced by a fore-and-aft horizontal tie rod, secured to the corresponding leg on the cylinder casings.

Besides the above-mentioned stays, each cylinder of one engine will be stayed to the corresponding cylinder of the other engine.

The cast-steel bed plates, each in three sections, are bolted together by body-bound steel bolts. Each bed plate has two longitudinal girders and six cross girders of I section. The main bearings consist of a lower rolling brass, supported by a flat-bottomed chuck and a cast-steel cap. Both the cap and the rolling brass are lined with white metal.

The crank shaft for each engine will be hollow, forged in two sections, each section having two cranks, the two sections secured by flanged couplings and taper bolts. The diameter of shaft will be 16½ inches with a 9½-inch axial hole. The crank pins will be 17½ inches in diameter with a hole 10 inches. The webs will be 10¼ inches by 19 inches.

The thrust shafts 15½ inches in diameter, with 9½-inch axial holes. Each shaft will have thirteen thrust collars, 2 inches wide and 24¼ inches in diameter, with spaces between of 4 inches for the "horseshoes." The screw propellers will be of manganese-bronze, or equivalent metal, finished smooth all over, tinned and burnished. All shafting will be hollow, and of open-hearth steel, Class A forgings. The connecting rods and piston rods and other reciprocating parts, with their bolts, will be of high-grade nickel-steel, annealed and oil tempered.

The main pistons will be conical and of cast-steel, except the high-pressure piston, which is of cast iron.

Each piston rod with an outside diameter of 7¼ inches will be

secured to a forged-steel crosshead, fitted with a slipper, lined with white metal.

The main guides are cast hollow, of iron, and bolted to cast-steel strongbacks secured to the framing.

Each main engine may be turned by means of wormgearing, driven by a two-cylinder steam engine with cranks at 90 degrees. This turning engine is secured to a separate foundation abaft the main engine.

There will be one main and one auxiliary condenser in each engine room. The main condensers, each with 10,375 square feet cooling surface, will be cylindrical, 6 feet 7 inches inside diameter. The steel shell will have double-butt joints, with angle irons riveted around each end to form flanges. The water chests will be of composition.

The tubes will be $\frac{5}{8}$-inch outside diameter and 13 feet long between tube sheets, the water passing through the tubes.

The auxiliary condensers will each have 550 square feet of cooling surface, with cylindrical shells made of steel plate and with heads of composition. Each auxiliary condenser will connect, through the auxiliary exhaust pipe, with all the auxiliary machinery.

A combined air and circulating pump, of approved size and type, will be fitted to each auxiliary condenser, forming a base for the same.

Each dynamo room also will have one auxiliary condenser, with combined air and circulating pump, for exclusive use of the dynamo engines. The cooling surface of each will be about 970 square feet.

The main air pumps, one in each engine room, will be twin, vertical, single-acting, the air-pump cylinders to be 30 inches in diameter, with two inverted steam cylinders of 12½ inches diameter and a common stroke of 20 inches.

The circulating pumps will be of the double-inlet centrifugal type, with suction and discharge nozzles 18½ inches in diameter. The runners, 42 inches in diameter, are calculated to make about 265 revolutions per minute.

There will be twelve water-tube boilers, of the Babcock and

Wilcox marine type, placed in six watertight compartments. The working pressure will be 265 pounds above the atmosphere.

The total grate surface will be at least 1,100 square feet, with a total heating surface of about 46,750 square feet.

The forced-draft system will consist of two blowers in each compartment, discharging into airtight fire rooms.

The main steam pipes will be of seamless-drawn steel, with wrought-steel flanges.

These pipes will be arranged symmetrically in two systems, one on each side of the center-line bulkhead, each system being independent of the other, except for a cross-connecting pipe fitted with stop valves, uniting the two systems near the main engines. Each system will be as follows: A 7-inch branch pipe will lead from each compartment of two boilers. These 7-inch pipes will take the steam directly from the auxiliary steam pipe, and so, indirectly, from the boilers. The branches from the forward first and second compartments will unite into a 9-inch pipe, the diameter of which will be increased to 11 inches at the junction of the connection from the after compartment, the last diameter continuing to the engine.

The auxiliary steam pipes, 7 inches in diameter, will extend fore-and-aft through the boiler compartments, one on each side of the center-line bulkhead. Each auxiliary steam pipe will connect with the main stop valves of all boilers, on its own side of the ship, through 5-inch branches, and will connect to the main steam pipe as mentioned above.

The auxiliary steam pipes, reduced to 6 inches diameter, will continue through part of the engine compartments.

Forward of the 5-inch connections from the forward boilers and forward of the engine-room after bulkhead the two auxiliary steam pipes will form connecting loops between the two sides of the ship.

The auxiliary steam pipe will have stop valves at each end and at intermediate bulkheads. In each engine room a 6-inch pipe with a stop valve will connect the auxiliary steam pipe with the main steam pipes.

The auxiliary exhaust pipe will be of sufficient size for all

steam auxiliary machinery in the vessel. Valves will be placed so that the exhaust steam may be led into either main or auxiliary condensers, low-pressure receivers, feed-water heaters, or into the atmosphere through the after escape pipe, at will.

There will be two dynamo rooms, one forward of the forward boiler-compartments bulkhead, and the other between the after boiler-compartments and engine-compartments bulkhead.

The steam pipes in the dynamo rooms will be so arranged that, in case of a break in the pipes, at least one-half of the dynamo engines in each room may be operated.

A feed suction main on each side of the ship, gradually reducing in size, will lead to the auxiliary feed pumps in the forward boiler compartment. From this suction main branches will lead to non-return screw-stop valves on the main feed pumps, and to the fresh-water manifolds on the auxiliary feed pumps.

From the main feed pumps in each engine room there will be a delivery pipe running forward to the boiler compartments with branches so arranged and valves so fitted that it may discharge into any or all of the boilers on both sides of the ship. The three auxiliary feed pumps on each side will discharge into a fore-and-aft delivery pipe feeding the boilers on its own side of the middle-line bulkhead; otherwise they will have branches and valves fitted similarly to the main feed system. The auxiliary feed pumps can also be used for fire and bilge pumps. There will be two main feed pumps in each engine room and one auxiliary feed pump in each boiler room. They will be vertical, double acting, single. There will also be in each engine room one fire and bilge pump, one water-service pump and one hot-well pump, and a bilge pump driven from the forward end of the crank shaft.

Each engine room will have one combined feed and filter tank of about 5,475 gallons capacity, and one feed-water heater with 825 square feet of heating surface.

The feed-water heaters will use the auxiliary exhaust for the heating agent.

Pipes and valves will be so arranged that the discharge from

the hot-well pumps may be passed through the heater or be by-passed.

The evaporator and distilling plant will consist of three evaporators and three distillers, with their accessories. The evaporators will have a combined capacity of 16,500 gallons, and the distillers to furnish 10,000 gallons of potable water per twenty-four hours.

The evaporators will be arranged so that they may all be operated in single effect, or the high-pressure evaporator may be used, with either of the others as low pressure, in double effect.

The general workshop will have two lathes, one column-shaping machine, one back-geared vertical drill press, one sensitive drill, one universal milling machine, one combined hand punch and shears, one emery grinder and one grindstone. All the above tools will be provided with the most modern attach ments; the material and workmanship will be of the best.

The ice machines will be capable of producing the cooling effect of three tons of ice per day.

ARMORED CRUISERS NOS. 10 AND 11, ARE TO BE NAMED "TENNESSEE" AND "WASHINGTON," RESPECTIVELY.

The general dimensions of the hulls are: Length on load-water line, 502 feet; breadth, extreme, over plating, 72 feet 8½ inches; displacement, 14,500 tons; draught, to bottom of keel, 25 feet.

The armament will consist of four 10-inch breech-loading rifles, sixteen 6-inch breech-loading rifles, twenty-two 3-inch (14-pounders) rapid-fire guns, twelve 3-pounder semi-automatic, two 1-pounder automatic, two 1-pounder rapid-fire, two 3-inch field pieces, two machine guns, .3 caliber, six automatic guns, .3 caliber.

General Particulars of the Machinery, Department Design.—The main engines will be right-and-left, placed in watertight compartments and separated by a middle-line bulkhead. The engines will be of the vertical, inverted-cylinder, direct-acting, triple-expansion type, with four cylinders, developing 25,000 indicated horsepower, with 250 pounds steam at high-pressure valve chest. The diameter of cylinders will be: high pressure,

40 inches; intermediate pressure, 65 inches, and two low-pressures, 75 inches each; the stroke of all pistons being 48 inches. The engines will turn inward when going ahead, the starboard propeller being left hand and the port right hand.

The cylinders and liners will be of cast iron, jacketed around the working liners and at both ends in such a manner that the jacket steam, entering at the top of the high-pressure jacket, will pass successively through each jacket finally emerging at the lowest point of the low-pressure jackets.

The main exhaust and receiver pipes will be of copper. The high-pressure pistons and followers will be of cast iron, the other pistons being of cast steel and their followers of cast or forged steel.

The piston rods will be high-grade forgings, $8\frac{1}{2}$ inches outside diameter; the inside diameters will be 3 inches for the high and intermediate rods, and $4\frac{1}{2}$ inches for the low-pressure rods, reduced to $1\frac{1}{2}$ inches and 3 inches respectively, at crosshead ends. The crossheads will be of forged steel and the slippers of cast steel, the ahead surface of the latter being 704 square inches for the low pressure and 996 square inches for the high and intermediate pressures.

The connecting rods will be hollow, high-grade forgings, 8 feet between centers, $8\frac{1}{4}$ inches diameter at crosshead end and $9\frac{1}{2}$ inches diameter at crank-pin end. The rods will be forked to span the crossheads. There will be two $4\frac{3}{4}$-inch bolts on crank end, and two $3\frac{1}{2}$-inch bolts on each side at crosshead end.

All main-engine valves will be piston valves, hollow and single-ported. There will be one for the high-pressure cylinder and two for each of the others.

The valve stems will be high-grade forgings, all $3\frac{1}{2}$ inches diameter at stuffing boxes, reduced to $2\frac{1}{4}$ inches through valves and $1\frac{3}{4}$ inches above valves, all fitted with balance pistons at the upper end.

The valve gear will be of the Stephenson type, with double-bar links, all valves worked direct, and the valve gear will be interchangeable as far as possible.

The eccentrics will be in halves, of cast iron and forged steel,

with 5⅞-inch faces and 5¼-inch eccentricity. Eccentric straps will be composition, and links, link blocks and suspension links high-grade forgings. The cylinders will be supported on twelve 6⅞-inch diameter steel columns, stayed and braced in the usual manner.

The shafting will be of Class A forgings, each length in one piece, finished all over, and with axial holes. The crank shaft will be in two sections, each section having two cranks. The main journals will be 19¼ inches diameter; crank pins, 20⅜ inches diameter by 24½ inches long. The webs will be 22½ inches wide and 11⅜ inches thick, chamfered. The crankshaft will have 11½-inch and crank pins 12-inch diameter axial holes.

The thrust shaft will be 18 inches diameter with 11 inches diameter hole, and will have thirteen collars, 27 inches diameter; collars 2 inches thick with 4-inch spaces between. There will be no line shaft, the thrust shaft coupling direct to the inboard coupling of the stern-tube shaft.

The stern-tube shaft will be in one section, supported by two stern-tube bearings, and will be 19¼ inches diameter, with 11¼-inch hole. The inboard coupling will be of the usual form. The outboard coupling will be a 25-inch diameter sleeve, 6 feet 1⅜ inches long, with a double taper inside to fit the end of the stern tube and propeller shafts.

The propeller shaft will be in one section, 19¼ inches diameter, with a 11¼-inch hole, hole tapered at each end. The shaft will have no composition casing, except at the bearings.

The nut securing propeller on shaft will be composition. The exposed portion of the outboard shafting to be painted with the same composition as the hull.

The propellers will be of manganese-bronze, with adjustable blades, and will be finished smooth, balanced, burnished and tinned all over; the thrust bearings of the usual horse-shoe type, the pedestals cast iron and the shoes cast steel faced with white metal. There will be two stern-tube bearings, a stern-bracket bearing and a strut bearing for each shaft, all fitted with lignum vitæ.

The reversing gear will consist of a steam-and-oil cylinder,

secured to the high-pressure cylinder. There will be a common piston rod, acting through a steel crosshead, and two connecting rods on two arms on the reversing shaft. The reversing arms will be slotted to allow for adjustment of the cut-off. There will be an oil pump, properly connected to reverse by hand.

The turning engine will be double, capable of turning the main engine with steam of 100 pounds pressure.

The working platform of the main engine will be on the inboard side, opposite the high and intermediate-pressure cylinder, and here will be conveniently grouped the working levers and the necessary gauges, counter, etc. Very complete lubricating and water-service systems will be installed; and provision will be made for lifting various parts of the machinery for overhauling and repair. The main condensers, one in each engine room, will be of steel, oval in shape, with composition water chests; each condenser will have about 15,625 square feet of cooling surface and 6,825 seamless-drawn, $\frac{5}{8}$-inch outside-diameter tubes, 14 feet long between tube sheets. There will be in each engine room an auxiliary condenser of 600 square feet cooling surface, connected to all the auxiliary machinery, and, in each dynamo room, a condenser of 700 square feet cooling surface for the exclusive use of the dynamo engines.

The main air pumps will be of the usual type, independent, double, vertical, single acting, one in each engine room, with pump cylinder 36 inches diameter, steam cylinders 14 inches diameter, and a common stroke of 18 inches. The suction pipe will be 13 inches diameter, and the discharge pipe 11 inches diameter.

The main circulating pumps will be double-inlet, centrifugal pumps, driven by independent compound engines of sufficient power to discharge 15,000 gallons of water per minute from the bilge, the revolutions not to exceed 245 per minute.

There will be the usual outfit of pumps, and, where practicable, they will be of the single-cylinder, vertical type.

There will be sixteen water-tube boilers in eight watertight compartments. The total heating surface will be about 70,720

square feet, the total grate surface not less than 1,661 square feet, and the working pressure 265 pounds. The grates will not exceed 6 feet 10 inches in length. All parts of boilers under pressure will be of wrought steel, there will be no screw joints in contact with the fire, and generating tubes will be straight and not less than 2 inches diameter. Tubes will be of cold-drawn seamless steel.

There will be four smoke pipes, each about 100 feet above the base line.

The forced-draft system will consist of blowers discharging into airtight fire rooms, there being two blowers in each boiler compartment. The blower engines will be balanced and capable of performing their work at 100 pounds pressure. Rotary engines or steam turbines may be used for this purpose, provided the steam consumption does not exceed 50 pounds per I.H.P. per hour.

The boilers will supply steam direct to the auxiliary steam pipes, which, passing along the outboard sides of the machinery compartments, unite at the forward and after ends, thus making a complete circuit, fitted with the necessary valves for cutting out various compartments. From the auxiliary steam pipe in each compartment a branch will run to the main steam pipe, which thus draws its steam indirectly from the boilers. In the engine room there is a cross pipe uniting the two main steam pipes, and also a cross connecting pipe joining the main and auxiliary steam pipes. From this latter cross pipe various auxiliaries are supplied, either the main or auxiliary steam pipes being available. The main and auxiliary steam pipes will be of seamless-drawn steel.

An auxiliary exhaust pipe, of copper, will make the circuit of the machinery compartments in a manner similar to the auxiliary steam, and will have branches, for all auxiliary machinery, to each condenser and to the after escape pipe. There will be branches from the auxiliary steam and exhaust pipes to the dynamo rooms. At the connections between auxiliary exhaust pipe and main and auxiliary condensers spring relief valves will be placed, opening towards the condensers, to regulate the press-

ure of the auxiliary exhaust steam when it is used in the feed heaters or low-pressure receivers.

All pipes and places where condensed steam can accumulate will be well drained, and, in general, where the water passed is hot, float traps must be used, while where it is comparatively low temperature expansion traps may be used.

There will be two feed-water heaters, of 1,250 square feet heating surface each.

There will be a very complete pumping system for drainage, feed, etc. The main feed, hotwell and fire and bilge pumps will be in the engine rooms, and the auxiliary feed pumps in the boiler rooms. The feed heaters will be placed on the main feed-pump suction pipes, but so connected with the hotwell pumps that the latter, drawing from the feed tanks, will discharge, through the heaters, into the main feed-pump suction pipes. The water chests of condensers, boilers, pumps, feed tanks, salt-water pipes, etc., will all be protected by zinc plates.

Each feed tank in the engine room will have a capacity of about 6,000 gallons, and there will be reserve feed-water tanks in the double bottom of 150 tons total capacity.

There will be a general workshop provided with the following tools: two screw-cutting extension-gap lathes, one-column-shaping machine, one drill press, one sensitive drill, one universal milling machine, one combined hand punch and shears, one emery grinder, one grindstone and six bench vises. The machine tools will be driven by electric motors.

There will be a complete evaporating and distilling plant, consisting of three evaporators of a combined capacity of 25,000 gallons per twenty-four hours, and three distillers of a combined capacity of 10,000 gallons per twenty-four hours. The evaporators will be one high pressure and two low pressure, so arranged that they may all be operated single effect or the high pressure used with either of the low pressures in double effect. There will be a complete heating plant and a 3-ton ice machine and cold storage plant.

Arkansas.—This monitor was given a builder's trial on July

17, off the Capes of the Chesapeake. Everything worked satisfactorily. Although the bottom of the vessel was foul, she not having been docked for seven months, she easily maintained a speed of 11.5 knots per hour, this being the contract speed. The air pressure carried in the fire rooms was .65 inch water.

On August 9 the official trial was run. The standardization trials were run off on August 7. On the official trial an average of 12.25 knots was obtained with 2,100 I.H.P.

We hope to give a full account of these trials in the November number of the JOURNAL.

Denver.—This protected cruiser was launched at the works of Neafie & Levy, Philadelphia, Pa., on June 1.

Grampus.—This submarine was launched on August 1, at the Union Iron Works, San Francisco, Cal.

Hull.—This destroyer, a sister ship to the *Hopkins*, described in the May issue of the JOURNAL, was launched on June 1.

Dale.—The following table gives the results of the standardization-trial runs of the destroyer *Dale* on April 26, 1902:

.....	1st double run.		2d double run.		3d double run.		4th double run.		5th double run.	
Direction.....	S.	N.	S.	N.	S.	N.	S.	N.	S.	N.
Duration, minutes and seconds.....	2'41.8	2'37.8	2'27.7	2'23 4	2'20.5	2'15.7	2'13.4	2'08.1	2'11	2'06.2
Total revolutions during each run, port.....	706	685	715	695	716	697	716	696	716	697
starb'd.	721	692	721	703	728	690	723	696	722	709
Mean revs. per minute during double run.. ...	263.1		292.05		307.4		324.8		331.75	
Mean speed during double run, knots.....	22.532		24.737		26.076		27.545		28.005	
Mean apparent slip of screws.....	15.47		16.39		16.27		16.29		16.67	
Steam in engine room, lbs., port.....	130	124	167	164	186	188	215	219	233	233
starboard.	128	127	166	165	189	194	216	220	233	233
Steam in 1st receiver, lbs., port.....	37	34	51	51	57	59	67	69	72	71
starboard.....	35	33	48	48	56	56	63	65	67	68
Steam in 2d receiver, lbs., port.....	1.2	1.3	3	3.1	5.3	5.7	7.3	8	10.3	10.2
starboard.....	.2	.2	6.3	4	9.3	11 5	10.6	11.6	12	11
Vacuum, inches, port*..	29	29	29.1	29.2	29.4	29.4	29.3	29.1	29	29
st'b'd.	26.5	26.1	26.3	26.2	26.2	26	26.1	26	26	26

* Port vacuum gauge incorrect.

On April 29th the one-hour full-speed trial of the *Dale* was run, and the mean speed of 26.62 knots obtained. The following table gives the data on this trial:

Time, P. M.	Mean revolutions per minute.	Steam pressures above atmosphere.			Vacuum.	Temperature of feed water, degrees.
		Steam pipe engine room.	1st receiver.	2d receiver.		
		Port Engine.				
12'35	.....	180	57	4.5	29.2	124
12'45	308	190	59	5.5	29 4	127
12'55	309.5	195	61	6	29.4	120
1'05	308	195	60	5	29 4	112
1'15	312	193	59.5	5	29.4	121
1'25	314.5	192	59	5	29.2	116
1'35	313.5	195	58	4.5	29.2	120
Mean.....	310.92	182.1	59.1	5.1	29.3	117 1
		(Port vacuum gauge incorrect.)				
		Starboard Engine.				
12'35	.....	180	53	7	26.5	125
12'45	312.5	190	56	9	26.5	115
12'55	313.7	200	58	9	26.5	120
1'05	316.7	198	57	8	26.5	110
1'15	321.6	200	58	8.5	26.5	115
1'25	322	195	57	8	26.5	110
1.35	322	200	60	10	26.5	120
Mean.....	318 08	194.7	57	8.5	26 5	116.4

Mean revolutions per minute of both engines for one hour, $\frac{318.08 + 310.92}{2} = 314.5$.
Mean speed of vessel = 26.62 knots.

The Trial Board reported: "That the vibration of the vessel, as a whole, when under way, was at all times moderate, and special attention is called to the fact that, at all speeds, the local vibration of the outside plating in the wake of the propellers was at no time excessive."

The *Dale* is a sister to the *Decatur*, a description of which vessel was given in the February number of the JOURNAL.

Maine.—This battleship had her builders' trial off the Capes of the Delaware on July 17. Everything worked satisfactorily, and a speed of 18.29 knots is reported to have been made. The official trial will take place about August 22.

Truxtun.—This destroyer was given her standardization runs on June 25, the highest speed made being 29.582 knots, at a mean of 328.65 revolutions. On June 26 the one-hour official trial was made, at a speed of 27.67 knots, with 304.35 revolutions. The displacement was about 486 tons. A full account of these trials will be given in the November number of the JOURNAL.

Whipple.—This destroyer was run over the measured mile on July 17, the greatest average speed made being 28.438 knots, with 316.7 revolutions. On July 18 the official one-hour trial

was made, with the following result: Speed, 27.44 knots; revolutions, 299.59. The displacement for the trial was about 490 tons. These trials will be fully given in the November number of the JOURNAL.

ARGENTINE.

Majpu—Charbues.—Two battleships to be given these names have been ordered from Ansaldo of Genoa.

The principal features are: length between perpendiculars, 426.5 feet; beam, 78.1 feet; greatest draught, 27.06 feet; coal supply, normal, 1,000 tons; displacement, 14,000 tons; I.H.P., 18,000; speed, 21 knots; armament: four 30-cm., four 20-cm., twelve 15-cm., sixteen 76 mm., two 75-mm., eight 47-mm., four mitrailleuse and four torpedo tubes.

ENGLAND.

Bedford.—H. M. S. *Bedford*, the first of the armored cruisers of the County class to be completed, has finished her contract trials. The mean results of the first thirty-hours' coal-consumption trial, with the engines working at low power, were as follows: Steam at engines, 238 pounds; in boilers, 255 pounds; vacuum, starboard, 26.8 inches, port, 26.3 inches; revolutions, starboard, 85, port, 84; indicated horsepower, starboard, 2,250, port, 2,272, total, 4,522; speed, 14.92 knots; coal consumption, 1.91 pounds per indicated horsepower per hour. The mean results of the second thirty-hours' trial were: Steam in boilers, 246 pounds, at engines, 222 pounds; vacuum, starboard, 25.6 inches, port, 27.1 inches; indicated horsepower, starboard, 7,952, port, 8,053, total, 16,005; air pressure, .26 of an inch; speed, 21.2 knots; coal consumption, 1.97 pounds per indicated horsepower per hour. In her eight-hours' full-power trial the engines worked excellently throughout, but the estimated speed of 23 knots was not maintained, the mean being 22.7 knots. This result was the more disappointing because the engines were driven at considerably above the 22,000 indicated horsepower calculated as the maximum when they were designed. The mean results were: Steam in boilers, 285 pounds; steam at engines, 228 pounds; air pressure in stokeholds, .32 inch;

vacuum, starboard, 26 inches, port, 25.5 inches; revolutions, mean, 146.9; indicated horsepower, starboard, 11,286, port, 11,171, total, 22,457; coal consumption, 2.12 pounds per indicated horsepower.

Challenger.—The float-out of the second-class cruiser *Challenger* took place at Chatham Dockyard on Tuesday, the 27th of May. The ship, which was designed by Sir W. H. White, was laid down on December 1, 1900, and it is not expected that she will be completed until the middle of the next financial year. Her principal dimensions are as follows: Length between perpendiculars, 355 feet; extreme breadth, 56 feet; draught of water, forward, 19 feet 3 inches, aft, 21 feet 3 inches; displacement, 5,880 tons. The contractors for the machinery are the Wallsend Slipway and Engineering Company, Limited. The engines are of the four-cylinder, inverted, vertical, triple-expansion type, with two sets of cylinders, 28 inches, 45 inches, 52 inches and 52 inches in diameter for each set respectively, the length of the stroke being 2 feet 8 inches. When working at 12,500 indicated horsepower the number of revolutions will be 180 per minute. The ship is fitted with twin screws of 13 feet 6 inches diameter, and they are arranged so that the pitch can be varied. There are twelve boilers of the Babcock and Wilcox type. The armament comprises eleven 6-inch breech-loading guns, one 12-pounder 8-cwt. quick-firing gun, eight 12-pounder 12-cwt. quick-firing guns, six 3-pounder quick-firing guns and six .303 Maxims. The coal capacity of the vessel is 1,225 tons. The weight of the ship when floated out will be about 3,000 tons.

Drake.—The above armored cruiser, which has been built at Pembroke, and engined by Messrs. Humphrys, Tennant and Co., was taken, on June 21st, into Portsmouth Dockyard, on the completion of her trials, to be brought forward for sea. At her eight-hours' full-power trial on June 20, when she made four runs over the deep-sea course, she drew 26½ feet fore and aft, and the steam pressure in the boilers was 292 pounds. The vacuum was 26.25 inches starboard and 26.5 inches port, while the revolutions were exactly 116 starboard and port. The total collective I.H.P. was 30,557, which gave the ship a mean speed of 23.03

knots. The coal consumption was 1.83 pounds per unit of power per hour, and the total loss of water was 34 tons. The *Drake* and the *Good Hope* made identically the same speed at their full-power trials.

Chief interest attaches to the alterations made in connection with the propellers to determine the efficiency as compared with those on the sister ships *Good Hope* and *Leviathan.* All three ships are alike in their model; their machinery is of the same dimensions, differing only in detail. The propellers are of the same diameter—19 feet 2 inches—and the form of blades is the same; but the pitch can be varied, and the Admiralty decided to try successive ships with the screw blades set at a different pitch in each vessel. Thus there is being obtained a series of results with full-size vessels on a problem in propulsion about which relatively little is known, although it is of first-class importance.

MEAN RESULTS OF SPEED TRIALS OF H. M. SS. "DRAKE," "LEVIATHAN" AND "GOOD HOPE."

Revolutions.	Indicated horsepower.	Speed in knots.	Percentage of slip.	Coal consumption, lbs. per I.HP.
		H. M. S. *Drake.*		
72.3	6,937	15.43	11.8	1.72
105.9	23,103	22.08	13.9	1.78
116	30,557	23.05	18	1.83
		H. M. S. *Leviathan.*		
71.2	6,481	15.238	8.5	1.76
107.6	22,900	21.96	12.8	1.75
122.1	31,592	23.25	18.7	1.94
		H. M. S. *Good Hope.*		
77.5	7,953	15.91	8.4	1.87
109.1	22,467	22.10	9.6	1.83
126.2	31,088	23.05	18.5	1.92

The *Good Hope* went through her trials with her propellers set at a mean pitch of 22 feet 9½ inches. The *Leviathan* was tried with her screws at 23 feet 9½ inches, and the *Drake* had them altered to a maximum possible, with the dimensions adopted, to 24 feet 6 inches. The *King Alfred*, which belongs to the same class, will shortly go upon her trials, and it is probable that she

will have new propellers made so as still further to increase the pitch. The results obtained are of great importance. The increased pitch, it is considered, improved the speed, for at full power the *Good Hope* steamed 23.05 knots, the *Leviathan* 23.25 knots, and although the *Drake* only made 23.05 knots, the steering was not quite satisfactory, the ship yawing badly. The loss in slip at full speed was less, being for the *Good Hope* 18.5, for the *Leviathan* 18.5, and for the *Drake* 18 per cent. A further advantage is in the reduction of revolutions for a given speed of ship. Thus the *Good Hope's* engines had to run 126.2 revolutions, the *Leviathan* 122.1, and the *Drake* only 116 revolutions.

A reduction of 80 feet per minute in the piston speed of such high-power engines is a great relief to bearing surfaces; and, other things being equal, there is here a justification for increasing the pitch. The same point applies to the results at three-fourths power; but here the slip has increased with the increase of the pitch. The *Good Hope* had only 9.6 per cent. slip, the *Leviathan* 12.8 per cent., and now the *Drake's* slip increases to 13.9 per cent.; but engineers do not require to be reminded that such an advance in slip does not necessarily mean less efficiency, as the question of frictional loss is a factor of importance. This increase in slip applies also to the low-power trials. The results are given in tabular form for all three ships. In each case the four low-power speed runs were made over the measured mile at Stokes Bay at the top of the tide, and the higher speed trials over the long deep-sea course between Rame Head and Dodman Point. The coal consumption results were obtained on the extended trial, which was of thirty hours' duration at one-fifth and three-fourths of the power, and of eight hours' length at full power. The *Drake*, which is 14,100 tons displacement, was built at Pembroke Dockyard, and engined by Messrs. Humphrys, Tennant and Co., London.—London "Engineering."

The Exmouth battleship, completed her thirty-hours' trial at four-fifths power, with the following results: speed, 18 knots; vacuum, 27.6 inches starboard, 27 inches port; revolutions per minute, 113.2 starboard, 112.8 port; indicated horsepower, 6,934

starboard, 6,840 port, total, 13,774; coal consumption per indicated horsepower per hour, 1.95 pounds. The engines worked smoothly throughout, and before the return to Plymouth the capstan and anchor trials were completed. The *Exmouth* returned to Plymouth on the completion of an eight-hours' full-power trial. The mean results were: Vacuum, 26.8; revolutions, 126.6; indicated horsepower, 18,346; speed, 19.05 knots. The machinery worked satisfactorily from start to finish.

Duncan and Class.—The six vessels which are now building or built of the type to which the name of Admiral Duncan has been selected to give the designation, and which will be hereafter known as the Duncan Class, are the *Duncan*, *Cornwallis*, *Russell*, *Exmouth*, *Montague* and *Albemarle*.

The *Duncan* was built by the Thames Iron Works, and was laid down on July 10, 1899. She is built on the usual bracketed-frame system with wing passages on each side to be used for carrying coal. She has a double bottom amidships with watertight flats at the ends of the vessel, thus having a double bottom from end to end.

The armor is of Krupp cemented steel, but of English make. The side protection consists of a belt which extends from the stem to within 140 feet of the stern. The belt is 14 feet in maximum depth. It is 7 inches thick amidships, and tapers to 3 inches thick at the fore end. It has a vertical extension of 5 feet below the water line and 9 feet above at the designed load draught, being carried to the height of the main deck for a length of 285 feet. Between the armor deck and the belt deck there is a screen bulkhead aft, which joins the after barbette to the side armor, and abaft this 1½-inch mild-steel plating in three thicknesses. The armored deck is arranged according to the principle now adopted in ships of this class, its sides meeting the lower edges of the belt. It has sufficient curve to rise to 2 feet 6 inches above the water line amidships, and is 1 inch thick. The main deck is 2 inches thick over the citadel, thus adding to the protective features. The two barbettes are circular in plan, and are placed on the fore-and-aft center line. The armor on them has a maximum thickness of 11 inches, and runs to a height

of 3 feet above the upper deck. There are eight watertight casemates on the main deck and four on the upper deck, all of Harveyed armor on the outside, and having armor plating at the back to protect the guns' crews from explosive shells.

The vessel is fitted with twin screws, the propelling engines being supplied by the Company's works, at Greenwich. They are triple-expansion engines with four vertical cylinders, each of the collective power of 9,000 horses, giving an aggregate of 18,000 horsepower. The cylinders are 33½ inches, 54½ inches and 63 inches in diameter, with a stroke of 4 feet, and the number of revolutions 120 per minute, when developing 18,000 indicated horsepower. There are two main condensers, having a cooling surface of 19,000 square feet. There are twenty-four Belleville boilers, having a total collective heating surface of 43,260 square feet, and a fire-grate surface of 1,375 square feet.

The *Duncan* is fitted as a flagship, accommodation being provided for an admiral and officers, or a total complement of 778 officers and men.

Her principal dimensions are: 429 feet length over all; 75 feet 6 inches extreme breadth; 43 feet 9 inches depth top of keel to upper deck, with 26 feet 6 inches mean draught of water.

The total cost, including equipment, is estimated at £1,070,408. —"Engineers' Gazette."

Encounter.—At Devonport, on the 19th of June, the second-class cruiser *Encounter* was launched. Her principal dimensions are: Length between perpendiculars, 355 feet; beam (extreme), 56 feet; draught, forward, 19 feet 3 inches, aft, 21 feet 3 inches; displacement (designed), 5,915 tons; I.H.P., 12,500; speed at full power per hour, 21 knots. The machinery consists of two complete sets of vertical triple-expansion engines, having cylinders of 28 inches, 45 inches and 52 inches diameter, and stroke of 32 inches, in separate engine rooms; each set being designed to develop 6,250 H.P. The boilers, twelve in number, of the *Encounter* are water-tube, of the Dürr type. She is of the unarmored protected type of vessel, the protection consisting of an arched deck varying in thickness from 3 inches and 2 inches

over machinery spaces to ¾ inch and ½ inch at the ends, with a conning tower of steel 6 inches thick.

The armament consists of eleven 6-inch Q.F. guns, eight 12-pounder 12 cwt., six .303 Maxims, one 12-pounder 8 cwt. field gun, six 3-pounder Q.F. Hotchkiss guns, and two submerged torpedo tubes. She will have a total complement of 499 officers and men. The coal capacity of the new cruiser is 1,225 tons.

Europa.—This cruiser, which in the course of an extensive refit has received new boilers, has completed her steam trials in the Channel. At her thirty-hours' trial at four-fifths power she drew 24 feet forward and 27 feet aft, and had 257 pounds of steam in her boilers, the vacuum being 24.2 inches starboard, and 25 inches port. She developed 13,890 indicated horsepower, which gave 104 revolutions and a speed of 19½ knots, on a coal consumption of 2.07 pounds per unit of power per hour. At her eight-hours' full-power trial, she drew 24 feet 3 inches forward and 26 feet 3 inches aft, and had 262 pounds of steam in her boilers, the vacuum being 25 inches starboard and 27 inches port. She developed 16,823 indicated horsepower, which gave her 108.3 revolutions, and a speed of 20½ knots, on a coal consumption of 2.15 pounds per unit of power per hour.

Gossamer.—The full-power test of the *Gossamer* has proved successful, a mean speed of 20.32 knots being obtained. The gunboat will be at once completed for commission.

King Alfred.—This vessel arrived at Portsmouth from the Vickers Works on June 10. The machinery worked very well during the run, which was made at a speed of 18 knots. She is being prepared for her trials. Launched on the 28th of last October, this vessel has been practically completed in less than eight months from the date of launching.

Steam Trials of H. M. S. Leviathan.—The first-class armored cruiser *Leviathan*, built by Messrs. John Brown & Co., Limited, Clydebank, for the British Navy, completed within a short time her contract steam trials, with very satisfactory results, the full power developed being, on the eight hours' test, 31,203 indicated horsepower, while the mean speed on four runs over the long deep-sea course was 23.25 knots. The design

anticipated 23 knots, with the engines developing 30,000 indicated horsepower. The *Leviathan* is the second of the four vessels of the *Drake* class to be successfully passed through her steam trials, and, as on the occasion of the *Good Hope's* performance we wrote fully as to the chief elements of design, it is only necessary here to give one or two general particulars. The length is 500 feet; width, 71 feet; and when in fighting trim she will displace 14,100 tons, the draught then being 26 feet. The vessel carries 2,600 tons of fuel in her bunkers, and will therefore be able to steam at a cruising speed of 14 knots for 12,500 sea miles, equal to a voyage from Portsmouth to Melbourne, without renewing her fuel supply.

The propelling machinery consists of two sets of four-cylinder triple-expansion engines; each of the two sets is designed to develop 15,000 indicated horsepower, steam being supplied by forty-three water-tube boilers of the latest Belleville economizer type, working at a pressure of 300 pounds per square inch. All engine cylinders are fitted with separate liners and are steam-jacketed. The diameter of the high-pressure cylinder is 43½ inches, that of the intermediate cylinders 71 inches, and that of the two low-pressure cylinders 81½ inches, each having a stroke of 48 inches. The high-pressure cylinder is fitted with one piston valve of the inside type, the intermediate cylinder is fitted with two piston valves, having adjustable packing rings, whilst the two low-pressure cylinders are fitted with double-ported flat slide valves, having a special type of relief ring. There are two air pumps on each engine, worked by lever in the usual manner from the main engines. The main condensers are four in number, of cast gun metal, having a collective cooling surface of 32,000 square feet. There are two condensers to each set of engines—one forward and one aft, bolted to the back columns and resting on a seat. At the aft end of each engine room is placed an auxiliary condenser, having a cooling surface of 1,830 square feet. Under each auxiliary condenser is placed a combined air and circulating pump. Water is circulated through the main condensers by four 24-inch centrifugal circulating pumps,

each driven by independent engines, having, in addition to the suctions from the sea, the usual bilge connections.

The boilers are placed in four separate compartments, there being in all eight stokeholds running athwartships. The forward group in each boiler room consists of a single row of boilers, and the after group in each are placed back to back. There are thus forty-three boilers with economizers, viz: Five boilers having 10 elements, with 8 element economizers; twenty-eight boilers having 9 elements, with 7 element economizers; and ten boilers having 8 elements, with 6 element economizers. The total heating surface is 71,970 square feet, and the grate area 2,310 square feet, the weight of machinery being approximately 2,500 tons.

The armament includes two 9.2-inch guns, sixteen 6-inch guns, and a large number of 12 pounders and automatic guns. The main and auxiliary machinery and boilers and the magazines are protected by a water-line belt 11 feet 6 inches deep, extending over half the vessel's length, and varying in thickness from 6 inches amidships to 4 inches at the ends. At the after end of this belt a 5-inch armored bulkhead is fitted, and 2-inch nickel-steel protecting plating is fitted on the bows. Abaft the screen bulkhead is a protective deck 2½ inches thick, affording protection to the steering gear and after capstan, &c. Within the citadel two protective decks are worked, the upper being 1½ inches thick, and the lower 1 inch thick. The 9.2-inch guns are protected by 6-inch barbettes, in addition to gun shields. The 6-inch guns are each inclosed in a separate casemate, these being formed of 5-inch hard-faced armor. The conning tower is of 12-inch armor, with an armored tube 7 inches thick, affording protection to the controlling gear, &c.

Turning now to the steam trials, it may be said at the outset that special interest attaches to these, as a change was made in the pitch of the propellers, so as to make possible a comparison of the results with those got with the *Good Hope*. Both ships are alike in form; the machinery is of the same dimensions, even to the propellers, which are 19 feet 2 inches in diameter. On the trials of the *Good Hope* the blades were set at a pitch of 22 feet

9½ inches, and it was decided to give the *Leviathan's* propellers an altered pitch, which is now 23 feet 9½ inches, and to make observation of the result on the speed of the ship. It was not deemed necessary to make the same series of progressive speed trials as in the case of the *Good Hope*, and only at three speeds are data available—at 15¼ knots, which represents the rate for one-fifth power; at 22 knots, the speed at continuous steaming power; and at 23 knots. From the results set out in the appended Table I, it will be seen that although at full power there is a slight gain in speed in the case of the *Leviathan*, the *Good Hope* did a shade better for the same power at 22 knots; and as to slip, there is a rise to the same maximum at 23 knots, which characterized the progressive speed curve. The revolutions of the *Leviathan* are also slightly less, as one would expect from the coarsening of the propeller pitch.

TABLE I.—MEAN RESULTS OF SPEED TRIALS OF H. M. SS. "LEVIATHAN AND "GOOD HOPE."

.....	Revolutions.	Indicated horsepower.	Speed in knots.	Percentage of slip.
Leviathan	71.2	6,481	15.238	8.5
	107.6	22,900	21.96	12.8
	122.1	31,592	23.25	18.7
Good Hope	77.5	7,953	15.91	8.4
	109.1	22,467	22.10	9.6
	126.2	31,088	23.05	18.5

The *Leviathan's* trials at 15 knots speed were made over the measured mile in Stokes Bay at the top of the tide, the depth of water then being quite satisfactory for the speed and draught; but the other trials at 22 and 23 knots were made at the deep-sea course, between the Dodman and Rame Head. Four runs were made on each occasion, and we have set out the results of each run at full speed in Table II. There was a stiff beam wind blowing, and the first and third trips were made to the westward. The mean of means, as given in Table II, was 23 25 knots.

As to the steam performances of the machinery, little need be said. The boilers worked well throughout, and the full power, the greatest yet maintained in a warship on an eight-hour trial,

TABLE II.—H. M. S. "LEVIATHAN'S" TRIALS.—MEAN RESULTS OF FOUR RUNS OVER DEEP-SEA COURSE (23 KNOTS) AT FULL POWER ON MAY 9.

.....	First run.		Second run.		Third run.		Fourth run.	
	Starboard.	*Port.*	*Starboard.*	*Port.*	*Starboard*	*Port.*	*Starboard.*	*Port.*
Mean steam in boilers, pounds	...	...	...	...	...	...	285	285
vacuum, inches	25½	25	25½	25½	25½	25½	25½	25½
revolutions	121.3	120.7	123.7	123.7	123 6	121.9	120.9	121
pressures in cylinders, high, pounds	111.6	106.7	113.5	109.4	113	109.1	109.8	106.5
intermediate, pounds	39	39	39	38.7	39.1	37.7	38.8	37.6
low, forward, pounds	20.8	20.3	21.8	20.7	21.8	21.2	21.6	20.8
aft, pounds	20.1	20.4	21 3	20.7	21.1	20.9	20.9	20 8
Indicated horsepower, high	4,871	4,630	5,050	4,870	5,025	4,790	4,780	4,640
intermediate	4,545	4,505	4,620	4,590	4,621	4,402	4.510	4,370
low, forward	3,182	3,085	3,395	3,220	3,394	3,250	3,290	3,175
aft	3,075	3,100	3,315	3,220	3,280	3,205	3,190	3,175
Total indicated horsepower	15,673	15,320	16,380	15,900	16,320	15,647	15,770	15,360
Gross total indicated horsepower	30,993		32,280		31,967		31,130	
Speed	23.26		22.98		23 63		22 88	

TABLE III.—MEAN RESULTS OF THE STEAM TRIAL OF H. M. S. "LEVIATHAN" IN THE ENGLISH CHANNEL.

Date	May 13 and 14. 30-hours' coal consumption at ⅔ full power.		May 15 and 16. 30-hours' coal consumption trial at ⅔ full power.		May 19. 8-hours' full power trial.	
Natural duration of trial	*Forward.* 26–1	*Aft.* 26–6	*Forward.* 26–2½	*Aft.* 26–3	*Forward.* 26–2	*Aft.* 26–2½
Draught of water, feet and inches	200		245		280	
Steam in boilers, pounds	*Starboard.*	*Port.*	*Starboard.*	*Port.*	*Starboard.*	*Port.*
Vacuum, inches	26	25	26	26	25.6	25.5
Revolutions per minute	70.6	70.9	107.3	107	121 2	120.8
Mean pressures, high, pounds	51.86	49 11	97.8	95.6	111	106 8
intermediate, pounds	13.68	11.80	34·7	34·9	39	38.3
low, forward, pounds	5.47	6.49	15.96	14.8	21.5	20.5
aft, pounds	5	6.24	15.32	15	20.7	20.7
Indicated horsepower, high	1,323	1,253	3,779	3,686	4,847	4,649
intermediate	929	802	3,575	3,589	4,530	4,446
low, forward	486	579	2,158	1,998	3,287	3,123
aft	444	556	2,072	2,025	3,165	3,156
Mean total indicated horsepower	3,182	3,190	11,584	11,298	15,829	15,374
collective indicated horsepower	6,372		22,882		31,203	
air pressure, inch	Nil		Nil		·35	
Speed of vessel	15.238		21.96		23.25	
Coal consumption per indicated horsepower per hour, lbs.	1.76		1.75		1.94	
Total loss of water, tons	24		95		32	

was got with only .35 inch of air pressure, which is far below the standard formerly set up as natural draft. The loss of water is an interesting feature. On the low-power trial it was 15 cwt. per hour, which for 6,372 indicated horsepower is quite satisfactory. At 22,882 indicated horsepower it was even proportionately less, being slightly over 3 tons per hour; and at full power it was practically at the rate of 1 ton per 8,000 horsepower per hour, or 4 tons in all per hour. The absence of vibration was also an important point. The engines worked splendidly, and it will be noted from Table III, giving the results of all three trials, that the proportion of power by the respective cylinders was uniformly maintained. In the low-power trial, with a steam pressure of only 200 pounds, the low-pressure cylinder power was somewhat less relatively to the other cylinders than in the later trials. But the best proof that everything went well is the fact that the trials only occupied a week, the vessel returning to Portsmouth dockyard on Tuesday, to have her engines opened up for inspection and to be otherwise prepared for commission. —London "Engineering."

No. 109.—Messrs. John I. Thornycroft & Co., Limited, Chiswick, have launched from their works a first-class torpedo boat, which will be known as *No. 109*. At the latter end of last year the firm received an order for five vessels closely resembling the four built by them in 1901, and *No. 109* is the first of them to leave the ways. The length is 166 feet; breadth, 17 feet 3 inches; speed, 25 knots, carrying a load of 42 tons. The engines are to be four-cylinder triple-compound, and the boilers are of the Thornycroft-Schulz type.

New Cruisers, Boilers for.—The Admiralty have decided on the following types of boilers for the six first-class cruisers of the 1901–2 program now under construction:

H. M. S. *Devonshire* (Chatham Dockyard)—A combination of four-fifths Niclausse and one-fifth cylindrical boilers.

H. M. S. *Hampshire* (Sir W. G. Armstrong, Whitworth and Co.)—A combination of four-fifths Yarrow and one-fifth cylindrical boilers.

H. M. S. *Carnarvon* (Messrs. Beardmore and Co.)—A combination of four-fifths Niclausse and one-fifth cylindrical boilers.

H. M. S. *Roxburgh* (the London and Glasgow Shipbuilding Co.)—A combination of four-fifths Dürr and one-fifth cylindrical boilers.

H. M. S. *Argyll* (the Greenock Foundry Co.)—A combination of four-fifths Babcock and Wilcox and one-fifth cylindrical boilers.

H. M. S. *Antrim* (Messrs. J. Brown and Co.)—A combination of four-fifths Yarrow and one-fifth cylindrical boilers.

Odin.—The new war sloop *Odin* recently completed, in the North Sea, her official steam trials, which were very satisfactory. This vessel, built at Sheerness dockyard, is of a type of which many are required to police the distant isles of the Empire. With 185 feet of length and 33 feet of beam, they displace 1,070 tons at their normal draught of 11 feet 3 inches. Under ordinary circumstances their great spread of canvas enables them to sail from point to point, but when baffled by contrary breezes or calms, the vessels resort to steam. They have twin sets of triple-expansion engines, and, although the total power is but 1,400 indicated horsepower, there are difficulties of design, since only 160 tons are allowed for boilers and engines and all auxiliaries.

The *Odin's* machinery has been supplied by the Wallsend Slipway and Engineering Company, and Mr. Andrew Laing, their general manager, was present at the trials. On the full-power run the steam pressure was maintained at 216 pounds in the four Babcock and Wilcox boilers, and the starboard engine, making 199 revolutions, indicated 709 horsepower, while the port set gave 711 indicated horsepower for 200 revolutions. The collective power was thus 1,420 indicated horsepower. The coal consumption was 1.54 pounds per horsepower per hour, while the speed of the ship proved to be 13½ knots. On the thirty-hour's trial at three-fourths power, the coal consumption worked out at 1.5 pounds per horsepower per hour, while the power was 1,026 indicated horsepower for 174 revolutions. The starboard engine indicated 516 horsepower and the port engine 510 horsepower. At the thirty-hours' trial at one-fifth of the full-power

rate, at which the most of the ship's steam cruising will be done, the fuel consumption was 1.52 pounds per horsepower per hour, the engines running at 122 revolutions, indicating 308 horsepower. On this trial the steam pressure was 208 pounds. The trials throughout proved most favorable.

Powerful.—The *Powerful* has had a two-hours' full-power trial after partial repair. Her mean draught was 28 feet 9 inches, as against 27 feet 6 inches, at her original trials, and during the two hours her mean horsepower was 23,508, while in the last half hour it was nearly 25,000. The mean speed of the two hours was 21.2, and in the last half hour 21.6 knots. Seeing that she got on her trial an hour and a half after starting, that her boilers are seven years old, that she had a scratch crew, and that her draught has been deepened 15 inches, the trial was regarded as highly satisfactory.

Queen and Prince of Wales.—The principal dimensions of these battleships are: Length between perpendiculars, 400 feet; breadth, extreme, 75 feet; mean load draught, 26 feet 9 inches; coal-carrying capacity, 1,920 tons; displacement, 15,000 tons; I.H.P., 15,000; speed, 18 knots. They are of steel throughout, and built on the longitudinal system, have no boat decks, and cowls are also dispensed with. They will be fitted respectively with two steel masts, each carrying a military fighting top and a searchlight platform. The masts are provided with three derricks, two forward and one in the mainmast, which will be of great utility when coaling. They will carry four steamboats and thirteen sailing and pulling boats. The armament will consist of four 50-ton breech-loading wire guns mounted in pairs in two barbettes, one forward and the other aft; twelve 6-inch breech-loading guns in casements, sixteen 12-pounder quick-firing guns, six 3-pounder Hotchkiss guns, two 12-pounder boat guns, and eight .303 Maxim machine guns. Four submerged 18-inch torpedo tubes will be arranged, two forward and two aft. The propelling machinery for the *Queen* is being constructed by Messrs. Harland and Wolff, Belfast, and for the *Prince of Wales*, by the Greenock Foundry Company, Greenock. The main engines of both ships are of the 3-cylinder type, the diameters being re-

spectively 31½ inches, 51½ inches and 84 inches, while the stroke is 4 feet 3 inches. The high and intermediate-pressure cylinders will be fitted with piston valves, and the low-pressure cylinders with flat valves, all worked by the usual link motion. Six forged-steel columns form the front supports of the cylinders, and the three back supports are of cast iron, having large bearing surfaces for the slippers. The bed-plates are of cast steel, having six main bearings 21 inches long. The crank shafting is 17 inches in diameter and the propeller shafting 17½ inches in diameter, all with a 9-inch central hole. The propellers are of manganese-bronze, four-bladed, and of a diameter of 17 feet 6 inches, with a pitch of 19 feet. The propellers turn inwards when the ship is being driven ahead. Two main condensers in each engine room are placed in the wings, and are capable of being worked together or singly, the total cooling surface being 16,000 square feet. The *Queen* is to be fitted with Babcock & Wilcox boilers, and the *Prince of Wales* with Belleville boilers. —London "Marine Engineer."

Russell.—The new first-class battleship *Russell* has successfully completed her trials. At her thirty-hours' run at one-fifth I.H.P. (3,600) the results were as follows: Draught of water, forward, 26 feet, aft, 27 feet 3 inches; speed of ship, 12.1 knots; steam pressure in boilers, 211 pounds; revolutions per minute, starboard, 74.8, port, 74.5; vacuum in condensers, starboard, 27, port, 27.3; mean I.H.P., high, starboard, 653, port, 755; intermediate, starboard, 579, port, 549; forward, low, starboard, 298, port, 354; aft, low, starboard, 295, port, 285; total, starboard, 1,825, port, 1,943—grand total, 3,768. The total consumption of coal was 271,730 pounds, which works out at 2.4 pounds per I.H.P. per hour.

The second trial was at four-fifths (13,500 I.H.P.), and the official details were as follows: Draught of water, forward, 26 feet 2 inches, aft, 27 feet 3 inches; speed of ship for 30 hours, 17.95 knots; steam pressure in boilers, 255 pounds per square inch; vacuum in condensers, starboard, 26.1, port, 25.8; revolutions per minute, starboard, 114.1, port, 113.6; mean I.H.P., high, starboard, 2,282, port, 2,427; intermediate, starboard, 2,195, port,

2,265; forward, low, starboard, 1,138, port, 1,138; aft, low, starboard, 1,128, port, 1,122; total, starboard, 6,743, port, 6,952—grand total, 13,695. The consumption of coal was 881,020 pounds, which works out at 2.14 pounds per I.H.P. per hour. In the full-power trial for eight hours the contract power was exceeded, and a speed of 19.3 knots was secured. The following table shows the results obtained at each trial:

.....	1st trial.	2d trial.	3d trial.
Duration, hours	30	30	8
Steam pressure in boilers, pounds	211	255	294
Vacuum, starboard engine, inches	27	26.1	25
port engine, inches	27.3	25.8	25.2
Revolutions, starboard engine	74.8	114.1	123.3
port engine	74.5	113.6	123.5
I.H.P., starboard engine	1,825	6,744	9,033
port engine	1,943	6,952	9,196
collective	3,768	13,696	18,229
Coal consumption, pounds	2.4	2.14	2.09
Speed of ship, knots	12.1	17.95	19.3

Seagull.—The results of the trials ordered by the Boiler Committee on the *Seagull*, the only vessel in the service fitted with water-tube boilers of the Niclausse type, have not turned out altogether satisfactory, although it is evident that this type, under other conditions, will show up to some advantage.

At the 1,000-horsepower trial for eight hours the coal consumption was 2.28 pounds per horsepower per hour, and the make-up feed water .32 pound. At the eight-hours' 3,000-horsepower trial the coal consumption was 2.15 pounds, and the make-up feed water .67 pound. The vessel next started on a fifty-hours' trial at 2,500 horsepower, and for the first eighteen hours the coal consumption was 2.14 pounds, and the make-up feed water .35 pound. The trial was then interrupted for six hours, owing to fog, and was resumed for nineteen hours at 2,300 horsepower, when the coal consumption was 2.47 pounds, and the make-up feed about the same as before. The weather becoming boisterous, and the coal running short, it was decided not to continue the run. The speed was not taken at any of the trials.

It will be seen that the lowest coal consumption was 2.14

pounds, and the highest 2.47 pounds. Taking the ideal consumption of coal per horsepower per hour as being 1.5 pounds, the Niclausse boiler suffers in this instance, as compared with other types. At no time, however, was there any difficulty in supplying the waste of water from the evaporators, and at the highest speed the *Seagull's* mean make-up was only 67 pounds per horsepower per hour. One advantage the Niclausse boiler may claim is that it is a steam generator which can be handled with more safety than the Belleville; it has no fusible plugs, for instance. In a larger ship we may get better results with the coal consumption, and the design of the Niclausse leads one to suppose that in a similar case the water endurance would be of a high character.—London "Marine Engineer."

Spartiate.—The *Spartiate*, cruiser, which was laid down at Pembroke more than five years ago, and was engined by Messrs. Maudslay, Sons and Field, has just completed her steam trials at Portsmouth. These trials have been spread over a long period, owing, first, to sand finding its way into the condensers; secondly, to the fusing of the white metal of the bearings; and, thirdly, to the extensive water leakage in the condensers, leading to the condemnation of the whole of the 12,000 condenser tubes. Several months elapsed between successive breakdowns, but at last the trials have been completely successful. When, in the morning, the *Spartiate* left Portsmouth, she drew 24 feet 7 inches forward and 26 feet 10 inches aft. Some time was spent in swinging for the adjustment of compasses, and early in the afternoon she started on her thirty-hours' trial at four-fifths her power. She had 258 pounds of steam in her boilers, and the vacuum was 27.2 inches starboard and 26.8 inches port. There was no air pressure, and with 14,000 indicated horsepower the revolutions were 111.06 starboard and 110.94 port. The speed by patent log was 19.8 knots, and the coal consumption 1.66 pounds per unit of power per hour. She anchored at Spithead at 9 o'clock the next night, after concluding this trial, and left again twenty-six hours later. She had worked up to full power two hours later, and then started on her eight-hours' final trial. She then drew 24 feet 4 inches forward and 26 feet 5 inches aft,

and the steam in her boilers was 260 pounds, the vacuum being 26 inches. There was a mean air pressure of .17 inch, and with 18,658 indicated horsepower the revolutions were 120.5 starboard, and 119.7 port, which gave the ship a speed, as measured by patent log, of 21 knots. The coal consumption was 1.65 pounds, and the total make-up feed water required was 25 tons. The *Spartiate* is the last of her class to complete her steam trials.

Submarine No. 2.—Further experiments have been made with the submarine boats at Barrow. *No. 2*, which has undergone important improvements, both in her steering and driving gear, was subjected to severe tests in the docks. The boat maintained a speed of 12 knots, running with her turret awash, against 10 knots, the result of her previous performance, while the speed submerged has been increased from 7 to 8 knots.

Submarine No. 5.—Another submarine boat, the last of the flotilla of five built by Vickers, Sons and Maxim, Limited, has been launched at Barrow. *No. 1* has been put through deep-sea trials under the supervision of Captain Bacon, to whom the Admiralty have allotted this special duty. So far the submarines have given the greatest satisfaction. A large special submarine boat, 100 feet long, is being built at Barrow, but it is not yet ready for launching.

Venerable.—The new first-class battleship *Venerable* has returned to Chatham on the conclusion of her machinery trials, which were satisfactorily completed in the short period of eight days. This time would have been shortened had it not been for a slight mishap to the machinery just before the eight-hours' full-power trial was to be started, which caused one day's delay. The vessel left Chatham on 20th May, and had a preliminary trial on the following day. On 22d May she left the Nore for a thirty-hours' coal-consumption trial, at one-fifth power (3,000 I.H.P.). The draught of water was 26 feet 7 inches forward and 27 feet 1 inch aft. With a steam pressure in the boilers of 225 pounds per square inch and the engines working at 65.3 revolutions starboard and 66.7 revolutions port, a speed of 11.45 knots was maintained. The vacuum in the condensers was 27.5 inches starboard and 27.1 inches port. The mean I.H.P. was

1,472 starboard and 1,610 port, giving a total of 3,082. The coal consumption was 2.01 pounds per I.H.P. per hour. The second thirty-hours' coal-consumption trial was at four-fifths power (11,500 I.H.P.), and this took place on 24th and 25th May. The draught of water was 26 feet 3 inches forward and 27 feet 1 inch aft. The steam pressure was 261 pounds per square inch, and the revolutions 101.1 starboard and 102.5 port, while the vacuum in condensers was 27.7 starboard and 27.5 port. The speed by log was 16.8 knots. The starboard engine developed 5,590 I.H.P. and the port engine 5,774, a total of 11,364. The coal consumption was 1.95 pounds per I.H.P. per hour. The eight-hours' full-power trial took place on 28th May, and again excellent results were secured. The details were as follows: Draught of water, forward, 26 feet 4 inches, aft, 27 feet 1 inch; speed of ship, 18.3 knots; steam pressure in boilers, 294 pounds per square inch; air pressure in stokeholds, .1 inch; vacuum in condensers, starboard, 26.8 inches, port, 27 inches; revolutions, starboard, 111.1, port, 112.4; mean I.H.P., starboard, 7,600, port, 7,745; total, 15,345. The coal consumption worked out at 2.145 pounds per unit of power per hour.—London "Times."

FRANCE.

Chateaurenault.—This vessel, whose trials have taken so long and marked by many unfortunate incidents, has at last made a final trial of her machinery. On this trial it is reported that she has exceeded all expectations. The mean speed over the measured course has been about 24 knots for two hours. The machinery worked very well and the vibrations of the hull have been very much reduced.

Jeanne d'Arc.—Further trials of this vessel have taken place, and it is reported that, due to the modifications made in her boilers, the temperature of the fire rooms has been much reduced, and that the results obtained have been good.

Jurien de la Gravière.—This cruiser had her preliminary trials on May 31, but, on account of a slight defect in one of her cylinder covers, only developed 17,400 H.P. and a speed of 22.75 knots,

in place of the designed speed of 23 knots. There was a moderate sea running at the time. It is fully expected that no trouble will be experienced in obtaining the designed speed on the official trials.

Justice.—Orders have been given to begin work on this new battleship. She will be of 14,865 tons displacement and 18 knots speed.

Montcalm.—In reports from French sources, the Normand-Sigaudy boilers of this vessel are giving perfect satisfaction. These boilers are double, with the furnaces arranged as in ordinary double-ended boilers. The steam drums are of large diameter so as to permit easy inspection of the interior and easy renewal of tubes. The diameter of the tubes has been greatly increased above that of the ordinary Normand type, so as to diminish the chances of their becoming choked, and their thickness has been increased, to give longer life.

Submarines.—Two mishaps occurred recently on board submarine boats of the submergible type. The first was on board the *Silure*. After she had been submerged for two hours the helmsman and two others of the crew were seized with syncope and became insensible. The officer in charge immediately caused the boat to rise to the surface and opened her up for thorough ventilation and returned into harbor at once. The men soon recovered consciousness. It is supposed they were asphyxiated by carbonic-oxide gas, the product of the combustion of the petroleum fuel used for surface steaming, which had not completely disappeared before submersion was effected, though this is the first time anything of the kind has happened. The second accident took place on board the *Triton*, and was caused by the bursting of a boiler tube, by which an officer had his face and hands scalded.—"Le Yacht" and "Le Temps."

Suffren.—The *Suffren* represents a considerable advance upon previous French ships, and is of further special interest in that the standard type—the recently laid down *Republique* class—is evolved from her.

The principal characteristics of the *Suffren* are as follows:

Displacement, tons	12,728
Length, feet	410
Beam, feet	70
Draught, feet	27½
Indicated horsepower	16,200
Designed speed, knots	18
Coal, normal, tons	820
maximum, tons	1,150
Boilers	Niclausse.
Screws	Three.
Guns: Four 12-inch, 40-calibers; ten 6.4-inch, 45-calibers; twenty 3-pounders; two 1-pounders.	
Torpedo tubes	Two submerged, two above water.

In addition to the ordinary fuel, liquid fuel is also carried. The armor, Krupp, is disposed as follows: A complete belt 12 inches thick amidships on the water line reduced to 8 inches at the ends. On top of this belt is a flat 3-inch deck, at the bottom of it a second flat armor deck, the space between being entirely filled with coal.

The lower deck is protected from the bow by a belt 325 feet long, 5 inches thick over the amidships portion, reduced to some 3 inches or so at the bow. Out of this upper belt rises the main-deck battery, a 6-inch redoubt, mounting four 6.4-inch guns at its angles. This redoubt curves inward in such fashion as to completely enclose the bases of both funnels, thus serving the same end as the continuous battery of the *Mikasa*, or American ships.

Thus far, it will be seen, the *Suffren* follows tolerably closely Anglo-Saxon ideas of construction, as opposed to distinctly French ideas. The only essential difference is that the very sound and complete French system of armor decks is adhered to, the complete belt being no longer a French specialty.

The rest of the *Suffren* is, however, fully French. The turrets, which are 12 inches thick, are essentially French. The heavy tower, common to British and American designs, is replaced by the usual French armored tube, which, in view of its thickness, is probably fully as efficient a protection as the huge erection we indulge in. The turrets themselves are balanced and elliptical, with those vertical sides to which the French consistently

adhere, holding that, since shot fall at an angle, inclined plates will really offer less resistance than vertical ones. Along the upper deck are six turrets, of 5-inch cemented Krupp armor.

The big guns have arcs of fire as follows: Forward turret, about 210 degrees; after turrets, 270 degrees. The fore-and-aft 6.4-inch turret guns all have arcs of 140 degrees or more from the axial line; the amidships turret, 180 degrees; the battery guns, from right ahead or astern to 20 degrees abaft or before the beam. Each of the 4-inch pieces fires through an arc of 135 degrees from the axial line. The submerged tubes bear on the broadside; the above-water ones are fixed to 45 degrees abaft the beam.

The broadside and end-on fires are respectively: Broadside, four 12-inch, five 6.4-inch, four 4-inch, one submerged tube; end-on, two 12-inch, six 6.4 inch, four 4-inch.

Those familiar with the French Navy will at once recognize that the *Suffren* is a "throw back" to the *Brennus*, one of the best ships ever designed so far as guns and armor go. The only difference between the two is that the *Brennus* carries but one big gun aft, and that the guns which in the amidship turrets of the *Suffren* stand on the redoubt are inside it in the *Brennus*, thus enabling the fore and aft turrets to be placed on the citadel with fully protected bases.

The ships most nearly akin to the *Suffren* are our *Canopus* class and the German *Wittelsbach*. A comparison of their fighting values may be of interest.

.....	*Canopus.*	*Suffren.*	*Wittelsbach.*
Displacement, tons	12,950	12,728	11,800
Guns	Four 12-inch, Twelve 6-inch, Ten 12-pdrs., Six 3-pdrs., Eight Maxims.	Four 12-inch, Ten 6.4-inch, Eight 4-inch, Twenty 3-pdrs., Two 1-pdrs.	Four 9.4-inch, Eighteen 6-inch, Twelve 20-pdrs., Twelve 1-pdrs., Eight Maxims.
Torpedoes, submerged	4	2	5
above water	Nil	2	1
Armor belt, inches	6-2	12-8	9-4
Lower deck side, inches	6-0	5-3	5-6
Deck, inches	2½	3	3
Turrets and braces, inches	12	12	10
Indicated horsepower	13,500	16,200	15,000
Speed	18.25	18	18
Boilers	Belleville.	Niclausse.	Thornycroft and cylindrical.
Coal normal, tons	1,000	820	650
maximum, tons	2,300	1,150 and liquid.	850 and liquid.

It may not be without interest to class these by the different characteristics of guns, armor, speed, coal endurance, &c.

.....	*Canopus.*	*Suffren.*	*Wittelsbach.*	By how much first is to the good of second.	By how much last is to the bad of second.
Guns	2	3	1	25½*	7½*
Torpedo	2	3	1	1 tube.	...
Armor	3	2	1	...	...
I. H. P.	3	1	2	...	...
Speed	1	2	2	.25 knots.	.25 knots.
Coal	1	2	3	1,200 tons.	300 tons.
Gen. ave. position	2	3	1	...	...

*Calculated by gun units.

The average position does not, perhaps, go for very much, since there is, by necessity, a good deal of comparing chalk and cheese about it; still it affords some index. The indicated horsepower is, perhaps, the most curious thing of any, the *Suffren* being allowed 4,700 more horsepower to .25 knot less speed, and the German ship, which is 100 tons the lighter, relatively even more. However, an explanation lies in the fact that the *Suffren* is dockyard built, while our *Canopus* class are engineered by contractors. The engines of the whole class can work up to a good deal over the required 13,500, and, to put the matter bluntly, our Admiralty have reduced to a fine art the getting of the maximum power for the minimum nominal expenditure.

For the rest, the comparison is an excellent illustration of the point made by Mr. Hurd in his recent book on "Naval Efficiency," that "we turn our ships into colliers." Neither her speed nor her coal endurance would assist the *Canopus* in a duel with either the *Suffren* or the *Wittelsbach*, and it is difficult to avoid admitting that she is, as foreign critics aver, neither one thing nor the other, lacking cruising speed and battleship armor. Strategically she is excellent, but there is not much point in being able to keep the sea while the enemy is coaling, if the enemy can then steam gaily out and win.—London "Engineer."

GERMANY.

German Naval Program.—By the German naval program three new high-speed cruisers are to be laid down. As those resemble the English *Amethyst* class recently ordered, the chief

points in design may be mentioned. They will be of less displacement but of slightly greater speed. The dimensions of the German ships will be 360 feet long, 40 feet 4 inches beam and 15 feet 9 inches draught, while the displacement will be 2,715 tons. The English new ships are to displace 3,000 tons and the relative speeds will be 22 knots and 21¾ knots. The German vessels will have engines of 8,000 I.H.P. against 9,800 I.H.P. in the case of the English vessels, which will thus have a greater margin for speed. The German cruisers will have ten guns of 4-inch caliber and ten 1.46-inch weapons. Three new battleships of 13,000 tons are to be ordered from the Wilhelmshaven, Kiel and Dantzig yards, respectively, while six battleships are to be finished before the end of the financial year. These new battleships are estimated to cost £1,243,000 each. Their speed is to be 19 knots, as compared with the 18½ knots of the *King Edward VII* class. They will have four 11-inch guns, each to fire two rounds every three minutes, eighteen 7.12-inch guns, twenty-four small pieces and six torpedo tubes. Three armored cruisers of 9,000 tons are to be pushed forward, and three protective-deck cruisers are also to be advanced, in addition to the commencing of three new vessels. Two river gunboats are to be laid down. Six torpedo-boat destroyers are to be completed, and six more of 350 tons laid down. The German program of new construction includes nine battleships, three armored cruisers, six protective-deck cruisers, two gunboats, and twelve torpedo-boat destroyers; and of these there are now to be commenced three battleships, three cruisers, two gunboats, and six destroyers. The new construction vote is £5,638,428, of which £3,758,300 is for hull and engines, £1,511,800 for artillery and torpedoes, and £368,328 for miscellaneous expenses.—"Marine Review."

Ægir.—The coast-defence battleship *Ægir*, belonging to the Reserve Division of the Baltic, has been paid off and sent to Danzig, where she will be lengthened similarly to the *Hagen;* her crew has been transferred to the *Heimdall*, a sister ship. The *Frithjof*, another of the class, is to be taken in hand for the same purpose at the Imperial Dockyard, Kiel.

Destroyers.—The Germania Yards, Kiel, have in hand a

number of torpedo-boat destroyers for the German Navy. Their length is nearly 206.8 feet; beam 22 feet; and displacement, 350 tons. *G 108*, the first of the new type to be launched, recently made a maximum speed at her trials of 28.8 knots in Eckernford Bay, where the water is shallow. In deeper water she is expected to add another knot to her speed.—"Marine Rundschau" and "Neue Preussische Kreuz-Zeitung."

Nos. 114 to 119, Destroyers, New.—Six 350-ton destroyers, 6,000 I.H.P. and 28 knots, have been ordered from Schichau.

H, J, K, L.—Of the four new battleships of the 1901 and 1902 programs, two, *H* and *L*, are being built in the Germania yard at Kiel; one, *J*, at the Schichau yard, and the fourth, *K*, at the Vulcan-Stettin. These ships will be far the largest yet constructed for the German Navy, as they have a length of 398 feet 6 inches, a beam of 72 feet 10 inches, a displacement of 13,000 tons and a speed of 19 knots, while the heavy armament will consist of four 40-caliber 28-centimeter (11.02-inch) so-called quick-firing guns, as they are reported to have a rate of fire of 90 seconds, the weight of the projectile being 760 pounds, with a muzzle velocity of 2,661 foot-seconds. It is doubtful if any of these ships will be ready for launching this year.

Kaiser.—The new first-class cruiser, which is to take the place of the old *Kaiser*, and for which a first vote has been taken in this year's budget, has been taken in hand at the Imperial Dockyard, Kiel. The new ship, like her sister the *Prinz Adalbert*, will be 396 feet long between perpendiculars, with a beam of 63 feet 9 inches, and a displacement of 9,050 tons on a mean draught of 24 feet; the displacement of the *Prinz Heinrich* the first of the class, being 8,870 tons. The ship will have three screws, and the engines are to develop 17,000 I.H.P., to give a speed of 21 knots. The armament will consist of four 21-cm. (8.2-inch) Q.F. guns in barbettes, two forward and two aft; ten 15-cm. (5.9-inch) Q.F. guns; twelve 8.8-cm. (3.4-inch) Q.F. guns; ten 3-pounder Q.F., and four machine guns, with four submerged torpedo tubes. The complement of the *Prinz Heinrich* is 500 officers and men, while that of the new ship is to be 550.

Prinz Friedrich Karl.—This vessel was launched on June 21,

at the works of Blohm and Voss, in Hamburg. She is an improvement in armor, in protection and in motive power on the *Prinz Heinrich*, with slightly greater displacement.

Her principal features are:

Length, feet	393.7
Beam, feet	65.62
Mean draught, feet	24.27
Displacement, tons	9,050
Engines, triple-expansion	3
I.H.P.	17,000
Boilers, Dürr	14
Coal, normal, tons	950
full, tons	1,500
Speed, knots	21

The armament consists of four 210-mm. guns in two turrets, forward and aft, with 150-mm. armor, the forward turret being elevated one deck above the after one; ten guns of 152-mm., six in casemates on the broadside on the gun deck, and four in small turrets on the upper deck; twelve of 88 mm., and ten of 37 mm. There are six torpedo tubes, one ahead, one astern and two on each beam.

The fire in line of the keel thus comprises two guns of 210 and four of 152 mm., ahead or astern. The fire on the quarters comprises four of 210 and five of 152 mm.

She will carry 550 officers and men.

Prinz Heinrich.—This armored cruiser, 8,900 tons displacement, had her official trials during May and June. With natural draft, she has given a speed of 18.16 knots with 11,355 I.H.P. at 111 revolutions, and a coal consumption of 1.91 pounds of coal per horsepower; with forced draft, 20 knots, 15,703 I.HP. and 126.5 revolutions, instead of the 20.5 knots and 15,000 I.H.P. expected.

Wettin, Wittelsbach, Zähringen.—The three first-class battleships of the 1899 program are now approaching completion. These are the *Wittelsbach*, under construction at the Imperial Dockyard, at Wilhelmshaven; the *Wettin*, at the Schichau yard, at Elbing, Danzig, and the *Zähringen*, at the Germania yard, Kiel. It cannot be stated definitely when the trials of the ships

in question will begin, but it is probable that both the *Wittelsbach* and *Zähringen* will be commissioned in the early autumn for that purpose. When ready these ships will take their place in the First Squadron, when the *Kurfürst Friedrich Wilhelm*, *Brandenburg* and *Weissenburg*, which have been in continual commission, both in home waters and in China, for nearly ten years, will be paid off for a thorough overhaul, new boilers and refit. The crew of the flagship *Kurfürst Friedrich Wilhelm* will probably be transferred to the *Wittelsbach*, while the crews of the *Brandenburg* and *Weissenburg* will also, in due course, be transferred to two of the new ships. Next year the two other ships of this class, the *Mecklenburg*, building at the Vulcan-Stettin yard, and the *Schwaben*, at the Imperial Dockyard, Kiel, should also be ready for their trials, the first-named in March and the last in November, 1903. They form part of the 1900 program. These five ships are an improvement on their five immediate predecessors of the *Kaiser* class, being some 16 feet longer, with a displacement of 11,800 tons, as against 11,150 of the earlier ships, and an increase of 2,000 I.H.P. in the engines, raising their speed from the 18 knots of the *Kaiser* to 19.

Zähringen.—The *Zähringen* is one of a group of five sister battleships generally known as the *Wittelsbach* class. Some time ago, when the type was in its earliest stages, we devoted an article to discussing it. Since then all the ships have been launched, and most of them are now approaching completion. As the finished article differs considerably from the original conception, we make no apology for returning to the subject now, for within its own strict limitations the *Wittelsbach* type may claim to be the finest battleship design yet realized. Owing to their relatively small displacement the ships have, of course, their compensation disadvantage, and this is their small coal supply. This stands at 650 tons, and though a nominal 1,000 tons maximum capacity is usually assigned to them in naval annals, some doubts exist as to whether they are designed to take even this moderate quantity. They are, in fine, coast defence ships "writ large," such vessels being in accord with German shipbuilding policy till very recently. This economy

of coal naturally tells in favor of other qualities. In speed they are quite equal, if not superior to, the normal battleships. In armor protection they leave little to be desired, while in gunpowder, there is no ship afloat to be compared with them, save it be the *Kaiser Friedrich III* class, which is gunned at the expense of armor.

The armor system of the *Wittelsbach* type we have already described, and it will only be necessary to go over old ground here sufficiently to refresh our readers' memories, and to bring to date older particulars.

The water line is defended by a complete belt of a maximum thickness of 9 inches, with which is associated a deck of 3 inches in thickness and a $1\frac{3}{8}$-inch splinter deck Along the lower deck, rising forward right up to the bow, cellulose is worked. Amidships for a length of 230 feet, and 7 feet high, is an upper belt, terminated by bulkheads that join the barbette towers. This belt is 6 inches thick, the barbettes—which rise up from the protective deck, and do not merely make a strip around the guns, as at first reported—are 10-inches maximum thickness. Above the upper belt on the main deck is a battery 50 feet long by $7\frac{1}{2}$ feet high, $5\frac{1}{2}$ inches thick, with $\frac{3}{4}$-inch screens between the guns, and $5\frac{1}{2}$-inch transverse bulkheads. Ten guns are in this battery, of which four fire right astern and two ahead, with arcs of about 135 degrees. The four middle guns train through about 110 degrees. Above this battery four guns are carried in 6-inch turrets. These have arcs of 150 degrees. Forward, around the base of the fore turret, are four guns in $5\frac{1}{2}$-inch casemates, all training from right ahead to some 45 degrees abaft the beam.

The after turret, with a 270-degree arc of fire, is on this level. On a higher level still is the fore turret, with an arc of some 240 degrees. The turrets each carry a pair of 9.4-inch guns, 40 calibers long. The eighteen battery, casemate and small turret guns are 6-inch of 40 calibers. On the flying deck are a dozen 3.4-inch 20-pounders, of which six train right ahead and six right astern.

Apart, then, from her heavy fire, the *Zähringen* has a large advantage in the high command of many guns. How great this

is we can best illustrate by a table showing the guns carried on the broadside and ahead on the different decks in comparison with some ships of about equal dates in other navies. This command of guns is comparatively little heard about, but in these days of long-range firing it is an exceedingly important point. The table is as follows:

Name	*Zaeh-ringen.*	*London.*	*Suffren.*	*Pobieda.*	*Maine.*	*Mikasa.*
Nation	German.	British.	French.	Russian.	U. S. A.	Japan.
Broadside guns :	*ins.*	*ins.*	*ins.*	*ins.*	*ins.*	*ins.*
Level of flying deck.	2 of 9.4	1 of 3	4 of 12	2 of 10	3 of 3	4 of 3
	6 3.4	...	4 4	2 3	...	...
upper deck.	2 9.4	4 12	3 6	2 10	2 12	4 12
	4 6	2 6	...	3 6	2 6	2 6
	...	4 3	...	4 3	...	4 3
main deck..	5 6	4 6	2 6	2 6	2 12	5 6
	...	4 3	..	4 3	6 6	2 3
Right ahead guns :						
Level of flying deck.	2 9.4	Nil.	2 12	2 10	2 3	4 3
	6 3.4	...	4 4	2 3	...	...
upper deck.	6 6	2 12	4 6	3 6	2 12	2 12
	...	2 6	...	...	...	2 6
main deck..	2 6	2 6	2 6	2 6	2 6	2 6
	...	4 3	...	...	...	2 3

These figures indicate very clearly how little, relatively, British and American designs have gone beyond the low freeboard period. Big guns have gone up one deck, and that is nearly all.

The grave defect of the *Wittelsbach* type in the matter of interference was dealt with in our first article. It is the result of too great seeking after end-on fire—a fire more useful in theory than in practice—for since, however designed, ships must ever be able to bring most fire from the broadside, it is broadside to broadside that they will generally fight. The end-on advance, bow to bow, is all very well on paper, but it is only one way of meeting out of many, and never, it may be said, bound to occur. Ships are infinitely more likely to converge on some common point, or nearly so. Naval warfare is not to be set out like a chessboard.

The *Wittelsbach* type has been criticised because she carries 9.4-inch instead of 12-inch guns. We do not incline to agree with this criticism, which is not in accord with the best naval thought. If 12-inch can be carried, it is well and good, but by sacrificing these the type gains three extra 6-inch on the broad-

side. The 9.4's are little inferior to 12-inch in penetration, but, were they so, there is little to show that armor penetration will decide a naval fight. It will help, no doubt, but all that is written about 6-inch guns attacking casemates and big gun turrets may be written off as moonshine. On land we hear nothing about picking out the eye or heart of the hostile soldier a mile off—we deem it a stroke of luck to hit him anywhere. The same must obtain at sea, and no ship will ever be able to afford to fire guns on the off-chance of hitting some relatively infinitesimal spot. The shell with a big bursting charge must ever be the chief projectile. The more this shell can penetrate the better, but only in so far as waste hits are thus rendered fewer. The 9.4's of the *Zähringen* are therefore no drawback to her worth mentioning when a gain of 6-inch pieces is considered.

It may here be remarked that these 9.4 do not, save experimentally, fire any faster than 12-inch. The Krupp system does not lend itself to rapid fire.

Like the *Kaiser* class, the *Wittelsbach* type is well supplied with submerged tubes. Besides the usual four there is a bow tube, which the Germans wisely adhere to. The idea that there is danger of running on to torpedoes from such tubes has never been borne out in practice. There are times when such tubes might be singularly useful. The absurdity of refusing them, as we have done, on the score of possible risk, is best evidenced by the fact that big guns, if fired ahead or abaft the beam, are certain to do some destruction—heavy, probably, if the operation be repeated—while rams are sure to greatly damage any ship using them. There is not a ship in the world that has trained her big bow guns as far aft as they will go, and then let both drive with full charges; nor is there a ship that would have much auxiliary battery left did she attempt it. Yet it is a far more likely accident in battle than overrunning a bow torpedo.

The *Zähringen* was built by Herr Krupp, at his Germania yard. She was laid down in November, 1899, and is to be ready for trials this August. The dates of laying down, builders, and completion dates of the ships of this class are as follows:

Name.	Builder.	Laid down.	To be ready.
Zaehringen	Krupp.	Nov., 1899.	Aug., 1902.
Wettin	Schichau.	Oct., 1899.	Oct., 1902.
Wittelsbach	Dockyard, Wilhelmshaven.	Sept., 1899.	Nov., 1902.
Mecklenburg	Vulcan Co.	May, 1900.	Mch., 1903.
Schwaben	Dockyard, Wilhelmshaven.	Nov., 1900.	Nov., 1903.

It will be noted that in Germany, as here, it takes longer to complete a ship in a dockyard than by contract. It is reported, however, that all these ships are somewhat delayed, and probably 1903 will be well advanced before any are in commission.

All the ships of the class are fitted with six cylindrical and six Schultz-Thornycroft boilers. In *H.* and *J.*, now building, the proportion of water-tube boilers will be increased. The mixture is adopted chiefly to ensure that men thoroughly trained in water-tube boilers shall alone use them. It has not, we hear, been a brilliant success, owing to the difficulties bound to occur from having two distinct types of stoker. In war, when steam for full speed is, of course, an absolute necessity, this bother is likely to be felt a good deal more.—London "Engineer."

ITALY.

Carlo Alberto.—This armored cruiser of 6,500 tons displacement, 13,500 I.H.P. and 20 knots speed, has had a series of combined coal and oil-consumption trials at Spezia. A speed of 17 knots was easily sustained with natural draft.

Francesco Ferruccio.—This armored cruiser was launched on April 23. Her principal characteristics are: Length, 344 feet; beam, 61.35 feet; draught, mean, 23.29 feet; displacement, 7,460 tons; engines (number), 2; type, triple expansion; I.H.P., 13,500; speed, 20 knots; normal coal supply, 700 tons; total coal supply, 1,400 tons; radius of action with normal coal supply at economical speed, 4,500 miles. Steam will be supplied by twenty-four Niclausse boilers, situated in four watertight compartments, two forward and two abaft the engines.

Garibaldi and Varese—Comparative Boiler Trials.—In view of the importance of all experience bearing upon the efficient boiler equipment of our warships, very great interest attaches to the experiments which have been recently carried out by the Italian Government to determine the relative values of boilers of different types. These experiments have been made on three large and precisely similar warships, but each fitted with a different type of boiler. The vessels were built by the well-known firm Ansaldo & Co., of Genoa, and were as follows: The *Garibaldi*, originally constructed for the Italian Government and eventually sold to Argentina, fitted with ordinary cylindrical boilers and forced-draft fans, delivering direct into the ash pits; the *Cristobal Colon*, laid down for the Italian Government and transferred to Spain, fitted with Niclausse boilers and assisted draft in closed compartments; and, lastly, the *Pueyrredon*, built for Italy and eventually disposed of to Argentina, fitted with Belleville boilers, without economizers, and working at full power with closed compartments and assisted draft.

These three vessels were built with exactly the same lines; they all had identically the same propelling machinery, with similar propellers, and the arrangement of piping was, as far as possible, the same in each case. Had it been possible to carry out the trials of these three vessels under precisely similar conditions, the results would have been far and away the most dependable of any yet obtained. Circumstances, however, prevented this; but it is known that, whilst in the vessel with cylindrical boilers 8,800 horsepower appeared to be the limit of power that could be obtained with natural draft for a prolonged trial, giving the ship a speed of about 18 knots, on the other hand, in the vessels fitted with water-tube boilers, enough steam was easily produced to develop over 10,000 horsepower at the main engines, giving the vessel a speed of over 19 knots.

It is therefore not surprising that the Italian Government since that date has resolved on having water-tube boilers for all new ships of war, and for the two latest vessels of the *Garibaldi* type has had the Belleville boiler fitted in the *Varese* and the

Niclausse in the *Giuseppe Garibaldi;* whilst the same rule has been followed for the two battleships now in construction, Belleville boilers being adopted for the *Benedetto Brin*, building at Naples, and Niclausse boilers for the *Regina Margherita*, now approaching completion at Spezia.

A decision has now to be made as to the type of boiler to be fitted in Colonel Cuniberti's two ships—the *Vittorio Emanuele III* building at Castellamare, and the *Regina Elena*, recently laid down at Spezia. At first it was decided to fit Belleville boilers for both; but finally it was determined, before coming to a definite conclusion, to institute a series of comparative trials between the *Garibaldi* and the *Varese* to test the relative capacities and advantages of the two types of water-tube boilers with which they are fitted.

A large Commission was accordingly nominated, consisting of Admiral Resasco, president, who had his flag hoisted on the *Dandolo;* Commander Serra, vice-president; Major Carini and Captain Traverso, of the Royal Naval Corps of Constructors; Fleet Engineer Cibelli and Staff Engineer Loverani, together with two other naval engineers and two chief engineers.

This Commission was divided into two equal parts, the idea being that one-half of the Commission should be on each vessel for the first trial, and then that they should change over for the next, and so on, so as to insure that each member should be in a position to judge fully of the relative merits of the two systems under trial.

The following extensive program of trials was drawn up:

Six hours' assisted draft, full speed, with all the boilers (24).

Twelve hours' natural draft, 9,000 indicated horsepower, with all the boilers.

Twelve hours' natural draft, with half the boilers (12).

Twelve hours' natural draft, with eight boilers, and finally another trial of six hours, full power, with natural draft (9,000 indicated horsepower), with all the boilers.

The following table gives the comparative dimensions of the two vessels and their propelling machinery:

.....	*Garibaldi.*		*Varese.*	
Constructor of vessel	Ansaldo.		Orlando.	
Built at	Sestri Ponente.		Leghorn.	
Length, feet	344		344	
Beam, feet and inches	59-9		59-9	
Draught, feet and inches	23-4		23-4	
Engines:				
Builder	Ansaldo.		Orlando.	
Place of construction	Sampierdarena.		Leghorn.	
Contract power, N. D.	9,000		9,000	
F. D.	13,500		13,500	
Diameter, H.P. cylinder, inches	42½		41	
I.P. cylinder, inches	63		63	
L.P. cylinder, inches	93		93	
Stroke, feet and inches	3-10		3-10	
Working pressure, pounds	155		155	
Boilers:				
Type	Niclausse.		Belleville.	
Place of construction	Sampierdarena.		St. Denis.	
H.S., elements, square feet	35,217		21,943	
economizers, square feet	.....		11,970	
total, square feet	35,217		33,913	
G.S., square feet	1,090		1,048	
Working pressure, pounds	212		214	
Propellers:				
Diameter, feet and inches	16		16-8½	
Pitch, feet and inches	23		23-4½	
Number of blades	4		3	
Trials:	N. D.	F. D.	N. D.	F. D.
Duration, hours	6	1½	6	1½
Steam pressure at boilers, pounds	176	204	155	201
Mean I.H.P.	9,948	14,713	9,479	13,843

All who have had the charge of trials of large warships fitted with water-tube boilers (or, indeed, with any type of boiler; but the difficulty is, perhaps, more accentuated with those of the water-tube type) will have experienced the considerable difficulty there is in obtaining regular firing and a uniform charging of the furnaces, so that the evaporation may be of the same degree of intensity in the different furnaces, and that this intensity may be varied in precisely the proportion desired to obtain the greater or less power required to be developed by the engines.

It is very clear that if it is left to the judgment of the leading stoker as to the quantity of fuel that should be introduced into one or other of the furnaces under his charge, he in his turn leaving it pretty much to the stokers themselves, they will naturally work by the momentary indications of the pressure gauges of

the boilers in that compartment and at that particular instant, causing thereby considerable oscillation of the steam pressure from one period to another; and, again, the stokers in one compartment under an active chief will fire up vigorously, their boilers giving the full amount of steam they are capable of; whilst in another compartment others, under a more indolent head stoker, seeing that the steam pressure is maintained, will content themselves with putting on just enough coal to keep up appearances, and the boilers served by them will consequently render but a small proportion of work compared with the others.

Besides these bad consequences of unequal firing, there is the very serious one that if the two compartments being worked at such different rates of combustion are served by the same chimney, the boilers with the grates more or less uncovered absorb most of its draft, and that uselessly, for the air, naturally taking the line of least resistance, finds its way more easily through the grates with less coal on them or partly uncovered. On the other hand, the draft is less in the boilers that are being vigorously fired and have the grates well covered, so that in these the combustion is taking place under most unfavorable conditions, both as regards the deficiency of air and the great loss of calorific energy that passes off with gas of imperfect combustion, whilst in the others we have a loss of efficiency due to the excess of cold air passing into the furnace.

These troubles are well known to those engineers who have to carry out trials of large steam-producing plants on board ship, and are, of course, more specially prominent in those navies of the world which are dependent upon conscription for their stokers, and therefore continually changing them, and which, as a rule, do little or nothing towards training them before sending them on board ship as able stokers. They have also been intensified of late by the introduction of water-tube boilers, for, to obtain good results with these, it is absolutely necessary to keep the extended grate surface completely but lightly covered with fuel, and this is altogether impossible save with regular and uniform firing.

The first thing to be done, therefore, to insure the necessary regular firing is to calculate the quantity of fuel to be put in each furnace mouth per given unit of time; secondly, to decide what interval of time between the periods of firing is the most convenient; and, lastly, to work out the best method of insuring that the stokers regularly charge the furnaces with the amount decided on at the regular intervals arranged for.

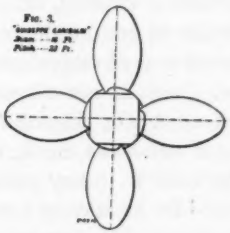
For each different intensity of evaporation there will, of course, be a different interval of time, and the most convenient way of carrying out the changes from one rate of evaporation to another is to have a table drawn up, showing the different rates of firing corresponding to the indicated horsepower required, or the number of revolutions to be made by the engines, and dividing these rates into a certain set of "grades," so that when a certain power or speed is required by the commander, the chief engineer simply gives the order to the stokehold for a certain "grade," and the watchkeeper at once finds in the table what the charge should consist of, and how many minutes should elapse between the charges. Such a table, which was prepared for the trials of the *Pueyrredon*, is given.

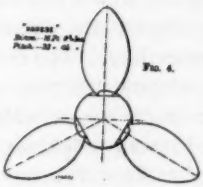
On the trials of the first vessel of the *Garibaldi* type fitted with water-tube boilers, as soon as it was seen that regular and equal firing was indispensable to a proper development of the calorific power of the boilers, a clock with a second hand was fitted in each stokehold, and tables as mentioned above and showing the different grades prepared for the use of the leading men, each of whom was furnished with a whistle with which to signal the moment when the firing of the furnaces under his charge should commence.

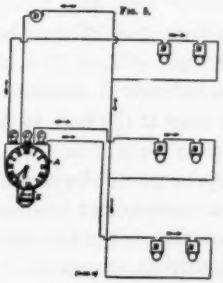
All those who have had to do with training stokers (who have been used to the old system of piling up coal in the front of a cylindrical furnace, letting it burn partly through and then pushing it back with the rake) to properly fire a water-tube boiler, with its extended grate surface, will know what a heart-breaking business it is to get them to understand what is required of them. But it is, perhaps, even more difficult still to induce the leading men, used to the old method of firing, to realize the absolute ne-

cessity of a thorough control over their men, and of insisting upon the instructions given them being implicitly obeyed and exactly carried out.

In the case of the *Garibaldi*, after the tables were made out, it, of course, depended upon the leading men to give the signal at the commencement of each period; but it was found almost impossible to induce them to be sufficiently particular in working to the desired periods of firing, and it soon became evident that it would be an immense advantage if the human and doubtful element could be eliminated and the signals be given automatically.







On these trials the stokeholds were in charge of Cav. L. Perroni, the manager of Messrs. Ansaldo's steel works at Cornigliano, and, realizing the need, he set to work at once to design an apparatus that would fulfill it, and so well has he succeeded that those who have had experience of it recognize it as an actual necessity wherever water-tube boilers are fitted on board ship, as well as a considerable advantage if fitted with cylindrical

boilers. The arrangement is shown in Fig. 5. *A* is a clock fitted in the engine room, and which replaces the clocks fitted in the different stokeholds, and in connection with which is the regulating apparatus, which may be considered as analogous to the chief engineer giving his orders as to the periods for the different rates of firing, whilst *B B* are electric bells fitted in each of the stokeholds (in this case six), to give the signal to commence firing, and which answer to the whistles of the leading men.

On the top of the clock in the engine room are a series of glow lamps, *C C C*, in connection with the different circuits, and which light up whilst the current is passing, thus showing in the engine room if the circuits are in good order, and the apparatus doing its duty. The current is preferably derived from the circuit for electric lighting, or, if this is not always charged, a series of cells can be provided as at *D*. The different grades are marked on an index plate *E* under the clock, there being a regulating handle with a pin to hold it in any desired position. As many grades may be arranged for as may be considered necessary, but in practical use it is found that, as a rule, five will be found sufficient besides the position *O*. When the handle is placed at this, the current no longer passes, and as the bells cease to ring all firing in the stokeholds is suspended. When the signaller is at work, the bells ring at the end of each desired interval for twenty seconds.

One great advantage of the apparatus will be noted at once, in that it leaves the leading man absolutely free to devote his full attention to his other duties. Another is the elimination of possibility of mistakes in the transmission of orders. In modern cruisers with watertight bulkheads carried up above the level of the water line, and no doors for communication between the engine and boiler rooms, it is necessary to transmit the orders by the voice pipes to the stokeholds, of which there may be as many as twelve or more in a 20,000 horsepower vessel, so that it is no easy matter to communicate the frequent changes of speed to the boiler rooms when cruising in company; but as the place of the uncertain communication by voice pipe is now taken

by the certain electric transmission, every possibility of error or misunderstanding is at once removed.

With this method the chief engineer has the rate of firing entirely under his own control in the engine room; and when orders from the bridge are given to alter the speed of the engines, all he has to do is to shift the key slightly to the new "grade" he requires, and, without noise, loss of time or possibility of error, the rate of firing adapts itself to the new rate of speed.

The stokers, too, find it an advantage, and after a little experience with it, their shovels go almost automatically to the coal as soon as the bell is heard to give its warning, and they find firing regularly and equally much less fatiguing than the old haphazard way. In practice it is also found to much reduce the anxieties of water minding, for, with absolutely regular firing with equal charges, the water level is maintained at an even height throughout, without any trouble whatever, even with hand regulating; and, indeed, it is found seldom necessary to touch the feed-regulating valve at all, so long as the same rate of firing is maintained. An apparatus as above described was constructed and fixed on board the Italian *Garibaldi* (No. 4) in time for the official trials, and was found admirably to fulfill the purpose for which it had been designed. Its use overcame all the difficulties that had formerly manifested themselves in obtaining regular and equal firing, with the result that the trials were very successful. It was afterwards retained on board for regular use, and the engineers reported that it was simply invaluable, and also conducive to economy of fuel.

When the Commission for the competitive trials was appointed, they began to inquire into the conditions on board the two ships, and in making their preparations they became aware that the *Varese* was not fitted with the Perroni signaller, so the trials were postponed for the moment and instructions given for it to be fitted on board. As soon as this was done a preliminary trial of the two ships took place, of the duration of twenty-four hours at two-thirds power, when eveything was found to be satisfactory.

Whatever may be the result of the forthcoming trials, it should

FIRING TABLE.

Grade.	Revolutions of engines.	Speed of vessel.	Indicated horsepower.	Approximate total consumption per hour.	Consumption per boiler per hour.		Number of shovelfuls per hour.		Interval between charges.	Number of shovelfuls per charge.	
					Wing doors.	Central door.	Wing doors.	Central door.		Wing doors.	Central door.
		Knots.		*Kilos.*	*Kilos.*	*Kilos.*			*Minutes.*		
I.	80	16	6,000	5,400	320	355	64	71	7·5	4	3
II.	84	16.8	7,000	6,300	374	414	75	83	6.5	4	3
III.	88	17.4	8,000	7,200	426	474	85	95	5·5	4	3
IV.	90	18.3	9,000	8,100	480	533	96	106	5	4	3
V.	95½	18.8	10,000	9,500	563	625	112	125	4.25	4	3
VI.	98½	19.4	10,750	10,450	604	672	121	134	4	4	3
VII.	...	...	11,500	10,925	647	719	129	144	3.75	4	3
VIII.	...	...	12,500	12,500	740	822	148	164	3.25	4	3
IX.	...	...	13,500	13,500	799	888	160	178	3	4	3

not be lost sight of that they can have no real value in determining the relative merits of the two types of boilers, and this cannot be too much insisted upon.

In two ships by different constructors, and with engines by different builders, there must be very many points of difference that it is absolutely impossible to eliminate by calculation or allowances, and yet they may make all the difference in the results as tabulated. In the case under notice, the two ships, although of equivalent displacement, are of different form; the propellers also are very different, that of the *Garibaldi* being four-bladed, as shown in Fig. 3, whilst that of the *Varese* has three blades, as shown in Fig. 4, so that to base final results on the amount of fuel consumed per mile run may be altogether misleading. The arrangement of steam piping also is different, and it is well known that the length and the arrangement of the steam pipes, and the amount of lagging upon them, are important factors in computing the indicated horsepower per weight of water evaporated.

And there are many other possible divergencies of practice that will occur to practical engineers which may make a considerable difference in the summing up, and yet be lost sight of, and lead to wrong deductions being made.

If evaporative tests are required, surely the proper place for them is on shore, in the shop; it is far more convenient, and the records can be obtained with much greater exactitude. On the other hand, if it is the practical working of the boilers on board ship that it is required to know, this can be best ascertained when the vessel is running under ordinary conditions, the boilers being handled by the ordinary crew of stokers, provided they are practical and efficient. The results thus obtained will be in many respects far more trustworthy and useful than those tabulated when running two ships against each other in competitive trials. We hope to deal further with these experiments later.—London "Engineering."

Turbine.—This 350-ton destroyer has had her forced-draft trials, the trial displacement being 270 tons. With a boiler pressure of 205 pounds 5,306 I.H.P. was developed at 369 rev-

olutions, giving a speed of 30.16 knots. On the coal-consumption trials at natural draft the I.H.P. developed was 3,257; revolutions, 313; speed, 25.2 knots, at an expenditure of 1.96 pounds coal per horsepower.

JAPAN.

New Ships.—The Government is providing for the construction, from 1904 to 1909, of four battleships of 15,000 tons, two 9,900-ton armored cruisers, four 5,000-ton protected cruisers, fifteen destroyers and fifty torpedo boats.—"Le Yacht."

MEXICO.

Destroyers.—Four destroyers have been ordered by this Government to be built by Ansaldo & Co., Sestri-Ponente, Genoa, Italy.

RUSSIA.

The Russian Cruiser Askold.—The *Askold* is one of that group of 6,500-ton Russian cruisers which contains also the *Bogatyr*, *Pallada* and *Variag*, with which we have already dealt. Special interest attaches to the ships of this class, in part because they are the result of completion in design, in part because they represent a solid and earnest attempt to continue a type discarded by all other nations. It is true that we have the *Encounter* and *Challenger* in hand, but these ships have neither remarbable speed, nor do they represent anything otherwise than a copy of ancient efforts. The Russian ships, on the other hand, are extremely fast—on trial, at any rate—and all embody something in the way of constructive novelties. The *Bogatyr* type, of which four new vessels are building in Russia, represents the application of the idea we used in the *Diadem*, casemates in a protected cruiser, applied to a vessel little more than half the size. The *Askold* represents, as we shall presently show, if not a new idea in the application of armor, at least internal armor applied more completely than has ever been attempted before. Krupp with the *Askold*, the Vulcan Company with the *Bogatyr*, and Cramps with the *Variag*, were all put in competition, one against the other. The prize, that of the best-liked vessel being copied in Russian dockyards, has gone to the Vulcan Company,

but as the *Bogatyr* is as yet hardly complete, the judgment can hardly be regarded as fully final. The fact is that all three are excellent in different ways. There is not room for that all-round excellence in 6,500 tons which cannot be secured in 16,500 tons.

So far as they go, the *Variag* represents most speed and least armor, the *Bogatyr* most armor and, probably, least speed, the speed difference being fractional in all three cases, for all are 23-knotters by contract. The *Askold* is more or less a mean between the other two. The only pity is that the interest of the competition was not heightened by Elswick, which invented craft of this kind, being put to work out the same design. The horny-handed son of toil was, however, either indulging in the "engineers' strike" or making up arrears caused by that struggle at the time the orders were given out, and the Russian Government wanted to be sure of getting its ships. Such, at least, is the avowed explanation in Russia for going everywhere except to this country. The data of the three types compared are as follows. The lengths are believed to be between perpendiculars in all cases, and the draughts mean ones:

.....	*Askold.*	*Variag.*	*Bogatyr.*
Builder	Krupp.	Cramp.	Vulcan Co.
Length (P. P.), feet	426¼	416	423
Extreme beam, feet	49	52	52½
Mean draught, feet	20¾	20	21¼
Displacement, tons	6,500	6,500	6,600
Guns	All carry twelve 6-in., twelve 3-in. (12-pounders), eight 3-pounders and two 1-pounders.		
Torpedo tubes	All carry two submerged and four above water, of which one is in the bow, one in the stern.		
Armor:			
Deck slopes, inches	2	3	2
Turrets (2), inches	4	Nil.	Nil.
Casemates (4), inches	4	Nil.	Nil.
Conning tower, inches	6	6	6
Hoists, inches	1½	1½	2
Funnel bases	1½-in., sloping.	Nil.	2-in. vertical.
Boilers	Schulz-Thornycroft.	Niclausse.	Schulz or Dürr.
Machinery, triple expansion.	3 sets.	2 sets.	2 sets.
Screws, number	3	2	2
Coal (normal), tons	720	(?)800	720
(maximum), tons	1,100	1,100	(?)900
I.H.P.	19,000	20,000	19,500
Contract speed, knots	23	23	23

It may here be observed that the *Variag* is reported to draw only 20 feet maximum draught, and all the displacements probably exhibit small inaccuracies. German publications—which ought to know—credit the *Bogatyr* with only six instead of a dozen 12-pounders, but Russian papers give her the same armament as the others.

In the matter of general features the *Bogatyr*, as our readers may remember, has a turret fore and aft. Each carries a pair of 6-inch, and the forward and after 6-inch guns are also in casemates, variously stated as 3½ inches and 4 inches thick.

The guns of the *Variag* are similarly placed to those of the *Askold*, save that the amidships 6-inch are dispensed with, and the poop and forecastle guns are doubled—a very unsatisfactory arrangement in a protected cruiser, as it puts two guns at the mercy of a single shell. Eight of the 12-pounders which are on the main deck in the *Askold* are in the *Variag* placed on the upper deck. The various fires are as follows:

	Broadside.	End on.
Askold,	seven 6-inch, six 3-inch,	five 6-inch, four 3-inch.
Variag,	six 6 inch, six 3-inch,	four 6-inch, two 3-inch.
Bogatyr,	eight 6-inch, six 3-inch,	four 6-inch, four 3-inch.

In commenting on these we may remark that the *Variag's* design exhibits most attention to serving the guns in action—a quality that shows little "on paper"—and the *Bogatyr's* least. Her guns are very mixed up. The *Askold*, having her 12-pounders all on a deck together, is, perhaps, little behind the *Variag*. In the matter of the best distribution the *Askold* is an easy first, but the *Bogatyr* has armor as a makeweight, and the *Variag*, as already observed, is the most easily served in action.

In the matter of groups, which mean fire control in action, the ships stand thus: *Variag*, two groups; *Bogatyr*, three groups; *Askold*, five groups. Since, however, the more easily they are controlled the more easily are they put out of action, it is impossible to say which is best.

The trial maximum of the *Variag* was 24.6 knots mean for eight hours, and 23.25 mean for twelve hours, at 16,270 indi-

cated horsepower. The *Bogatyr's* trials have not yet been run. The *Askold's* results are as follows: With 125 revolutions and indicated horsepower 20,390, a mean of 23.4 knots for six hours. On a second trial she did a mean of 20,420 indicated horsepower with 126 revolutions, and 23.8 mean speed. The maximum was 23,600 indicated horsepower and 24.5 knots. Consumption on the first trial was 1.87 pounds, and 182 on the second. The most remarkable point about the *Askold's* trial was a boiler test, given unexpectedly, an account of which appeared in the "Marine Rundschau" last month.

The ship was to proceed on trials, but the weather being foggy, these were countermanded. She has nine boilers, and all but one were out of use. The weather clearing, she received a sudden order to put to sea at full speed, and only two hours later was doing a steady 23 knots, which presently ran up to 24.4 knots. This performance of the Schulz, as the Thornycroft boiler is now called in Germany is very remarkable, and it is curious to reflect that in our battle of the boilers this type has not been mentioned. We, of course, have the Thornycroft in a few small cruisers, but in view of the way in which the Admiralty talk of quick steam raising in and out of season, it is certainly to be deplored that a prejudice against bent tubes should cut the record steam raiser out of the competition.

To resume: The special feature of the *Askold* is her deck. Instead of the usual deck, with inclined engine hatches slightly raised, the *Askold* has a high armor glacis to the bases of her five funnels. Whether the idea is originally Russian or "made in Germany" we cannot say, but it is distinctly good. Though all ammunition passages are now-a-days below the protective deck, there is still considerable importance attaching to the lower deck, and men with leak stoppers, &c., will have to work there in action. This big funnel glacis will go far to insure freedom for the dense clouds of smoke and steam likely to issue from pierced uptakes. As we have so often pointed out in the "Engineer," naval architects, as a class, are terribly prone to overlook all that funnels entail. We do not go quite so far as to say that a ship could be put out of action simply by holing

her funnels 'tween decks, but we are none the less convinced that a ship full of smoke and steam will be quite as handicapped as a ship with several guns knocked out. Such little actual war as has taken place has already pointed one or two nasty lessons in this direction; a big war will probably give more. It took designers a long while to realize that projectiles might hit elsewhere than on big guns or the water line amidships, and we incline to doubt whether there is not as much to learn yet as has been assimilated.—London "Engineer."

Bezuprechin.—This destroyer, of 350 tons displacement, 6,000 I.H.P. and 30 knots speed, has recently been launched at St. Petersburg.

Bogatyr.—It is reported that this protected cruiser of 6,550 tons displacement, has made her first official trial of twelve hours duration, developing 20,250 I.H.P. and a speed of 24.15 knots, in place of 20,000 I.H.P. and 23 knots expected.

Destroyers.—Work of construction has been started on six destroyers, the names of which will be *Givoi*, *Givnea*, *Ginsky*, *Giasky*, *Zavidni* and *Zavetni*.

Izumrud—Jemtchug.—The first keel plates of these two 3,100-ton protected cruisers were laid on June 14. They will be of 18,000 I.H.P. and 25 knots speed, and will have sixteen Yarrow water-tube boilers. They are of the *Novik* type.

Kephal.—This 312-ton destroyer, designed for 5,700 I.H.P. and 26 knots, has, on a five-hours' forced draft trial, developed an average speed of 28 knots, and made 28.5 knots during one hour.

Kniaz Potemkin Tavricheski.—The "Yuzhnaya Rossiya" (South Russia) publishes the following particulars of the new Russian battleship *Kniaz Potemkin Tavricheski*. She was begun in the Admiralty Yards, Nikolaieff, on December 27, 1897, launched October 9, 1900, and commissioned June 21 this year. Her length over all is 378 feet 6 inches, and at the water line 371 feet 2⅝ inches; beam, 73 feet; draught, 27 feet; displacement, 12,600 tons; engines, 10,600 horsepower; speed, 16 knots. She is fitted with Belleville boilers, the two groups aft being heated by coal and the one group forward by petroleum. Of

coal she carries 670 tons and of petroleum 580 tons, which together give her a radius of action of 3,393 miles at a speed of 9.3 knots. She is an improved type of the *Tri Sviatitelia* (Three Patriarchs). Her armor extends 237 feet along the load line on each side, with a thickness of 8 inches and 9 inches, and is continued to the ends fore and aft with a thickness of 3 inches; at the lower casemates it is 6 inches thick, with a run of 156 feet on each side, and at the upper casemates, or battery, for a length of 168 feet on each side, the thickness is 5 inches. The bulkheads at the terminations of the above-named armor are respectively, 7 inches, 6 inches and 5 inches in thickness. The lower steel deck is $\frac{5}{8}$ inch thick, with armor plates $1\frac{5}{8}$ inches on the horizontal and $1\frac{1}{8}$ inches on the sloping parts; it extends as far as the armor belt. All the armor is of Krupp steel, made in Russia, at the Izhorski Works. The upper armor deck has a thickness of $1\frac{1}{2}$ inches. The armament consists of four 12-inch Canet guns of 40 calibers, sixteen 6-inch Canet guns of 45 calibers, fourteen 2.95-inch Canet guns, six 1.85-inch Hotchkiss guns, six machine guns, two Baranovski landing guns, and five submerged torpedo tubes, one at the bows and four broadside.

Lossos.—This 312-ton destroyer has made her preliminary trials at Havre, and developed a speed of 28 knots, in place of 26 knots, as required.

Orel.—This battleship, whose construction was begun in September, 1899, has lately been launched. The principal characteristics are as follows: Length, 403 feet; beam, 77.43 feet; draught, 26.24 feet; displacement, 13,600 tons; normal coal supply, 1,250 tons; total coal supply, 2,000 tons; engines (number), 2, type, triple expansion; I.H.P., 16,000; boilers (number), 20, type, Belleville; speed (forced draft), 18 knots.

Pobieda.—The most remarkable thing about the Spithead fleet was the Russian battleship *Pobieda*, whose rig, by the way, has been altered since she was designed. She embodies a good many other minor improvements on the original design, and in the matter of novelty, was far in advance, not only of our latest ships, but also of the German, French and American. She is not yet complete, the shields to the casemate guns being still

absent; but she is fairly complete otherwise, and any of our engineer officers who saw her engine and boiler rooms must have wished themselves Russians. The *Pobieda* has a roomy and well-ventilated engine room—everything can be "got at"—and the same roominess distinguishes the boiler room. The boilers, it is interesting to note, run fore-and-aft, instead of athwartship, as in our modern vessels. Each room is fitted with an armored stairway, running right up to the main deck at an angle of 55 degrees, so the ship is unique in the matter of emergency exits. Viewed as a fighting machine generally, there is nothing equal to the *Pobieda* at Spithead, unless it were the American *Illinois*, of which more presently. The wide, open decks, of which the Russians are so fond, are much in evidence in the *Pobieda*, "shell-bursting gear" being almost entirely absent. The ship offers a huge target, quite half as much again as the considerably-larger *London*, but the distribution of the numerous 12-pounders is so excellent that the big target may be thereby discounted.—London "Engineer."

SWEDEN.

Armored Cruiser.—Plans for a new cruiser, which must be constructed in two years and for which an appropriation of $1,750,000 has been made, have been decided upon. Her principal features will be as follows: Length, 377.3 feet; beam, 48.88 feet; mean draught, 16.07 feet; displacement, 4,060 tons; I.H.P., 12,000; speed, 21.5 knots.

She will be fitted with an armor belt 100 mm. thick; deck, 37 to 50 mm.; barbettes, 100 mm., and superstructure, 50 to 125 mm. The armor will be of Krupp steel. The battery will be composed of eight guns of 150 mm., and fourteen of 57 mm. There will be two torpedo tubes.

Mode.—On the 22d ultimo, the 31-knot torpedo-boat destroyer *Mode*, built to the order of the Royal Swedish Government, was successfully launched from Messrs. Yarrow's Works at Poplar, in the presence of His Excellency the Swedish Minister and others.

TURKEY.

Abdul Hamid—Abdul Medjid.—These are to be the names of the new cruisers ordered from the Armstrongs and Cramps.

Their principal characteristics are: Length, 328 feet; beam, 42.65 feet; draught, 16.07 feet; displacement, 3,250 tons; I.H.P. (forced), 12,000; speed, 24 knots; armament: two 15-cm. guns, seven 12-cm., six 47-mm., six 37-mm. and two torpedo tubes.

Messudieh.—This reconstructed battleship has had her steam trials on May 28. The mean results were 9,050 I.H.P. at 105 revolutions. The maximum were 11,000 I.H.P. and 17.5 knots.

MERCHANT STEAMERS.

Kaiser Wilhelm II.—This new North German Lloyd steamship, was launched at the Vulcan Works, Stettin, on August 12.

Her principal characteristics are: length, 707 feet; beam, 71.5 feet; draught, 29 feet; displacement, 19,500 tons; I.H.P. 39,000. Accommodations for 1,000 cabin passengers. She is designed to be the fastest passenger vessel afloat.

Queen Alexandra.—The success last year of the *King Edward* has led to the construction of this new passenger steamer. She is on the same general lines as the older vessel; but is somewhat larger, being 270 feet long, 32 feet in molded breadth, and 11 feet 6 inches in depth to the main deck. She is for the same owners as the *King Edward*. A new feature in this vessel is the shade deck, extending some distance amidships, to which the passengers have access, and under which shelter is provided in wet weather. Were it not for this, the *Queen Alexandra* would so far resemble the *King Edward* that a photograph of one might almost be taken to represent the other. There is no need to describe the machinery, which is practically similar in design to that of the *King Edward*. The vessel, however, is considerably more powerful, having attained a mean speed of 21.63 knots, with 1,100 revolutions of the side shafts and 750 revolutions of the center shaft. The vessel is, we believe, the largest passenger steamer on the Clyde, and is also the fastest excursion steamer in Great Britain.

A preliminary run was made on May 12, which was most successful, and was attended by a large number of gentlemen interested in shipping and marine engineering. Captain Williamson, the managing owner, gives some figures as to coal consumption of the turbine machinery. A vessel of a similar type (the name of which he was not at liberty to state) steamed 12,106 knots in eighty days on a coal consumption of 1,909 tons, at an

average speed of 18½ knots. The *King Edward* steamed 12,116 knots in seventy-nine days on a coal consumption of 1,429 tons, and she averaged 18½ knots. Thus the turbine vessel steamed 10 knots more at the same speed on a coal consumption of 480 tons less. Mr. Parsons, in the course of some remarks that he made, said that last spring there were three turbine vessels under construction, but now there were seven, and he hoped that by this time next year the number would be increased in a geometrical ratio. His firm would have no hesitation in fitting an Atlantic liner with turbines, and in guaranteeing economy in steam power superior to that obtained with reciprocating engines.

It is worthy of note, as stated by Mr. James Denny, that the calculations had shown that the vessel would make 21½ knots if a certain boiler power were obtained, but that if everything was worked to its utmost limit 21¾ knots might be reached. Everything had not worked to its utmost limit, and a speed of 21⅞ knots was attained, which was exactly what had been anticipated. This, he said, proved that the turbine system was now on a sound basis, and could be adopted with a due knowledge of what it would do. The past year's service of the *King Edward*, and the fact that those who were best able to judge, namely, her owners, have put on another vessel as a commercial undertaking, shows that the steam turbine is fairly well established as a marine engine, and it may be confidently anticipated that it will play an important part, at any rate, in passenger and cross-channel steamers, doubtless leading to its adoption for larger craft. The fact that the Admiralty have taken it up for an ocean-going vessel supports this view. The *Queen Alexandra* is to run on the Campbeltown service, whilst the *King Edward* will be transferred to the route between Tarbert and Ardrishaig.—London "Engineering."

Spokane.—The preliminary trials of this vessel were reported in the February number of the JOURNAL. During these trials and the succeeding ones, the fire-room temperatures were exceedingly high, from 200 degrees to 208 degrees Fahrenheit, due to a faulty arrangement for supplying fresh air to the forced-draft blowers. This has now been remedied by arranging the

STEAMER *SPOKANE*.—VOYAGE FROM SAN FRANCISCO TO SEATTLE.

	Time.	Steam pressure.	Receivers. 1st	Receivers. 2d	Vacuum.	Counter.	Average revolutions.	Draft ash pit, natural draft. P.	S.	For.	Temperature feed.	Uptake draft. P.	S.	Uptake temperature	Thermometers. No. 1.	No. 2.	No. 3.	No. 4.
Sunday, June 8, 1902.*	A. M.							*in.*	*in.*	*in.*								
	10	172	30	5	26	664,781	...	...	...	...	115	—.6	—.6	...	98	96	...	...
	10·30	182	35	6	24½	667,381	86.6	...	...	...	120	—.6	—.6	...	98	96	...	...
	11	185	37	6	24½	670,096	90.5	...	...	...	135	— 6	—.6	...	100	96	...	...
	11·30	155	32½	3½	24½	672,727	87.6	...	...	...	135	—.6	—.6	...	98	96	...	...
	12	150	25	2	25½	675,268	84.8	...	...	...	140	— 6	—.6	...	104	96	...	...
	P. M.																	
	12·30	160	35	4	24½	677,584	77.2	...	...	...	135	— 6	—.6	...	99	96	...	...
	2	190	40	5	26	685,553	88.5	...	...	...	145	—.6	—.6	...	102	102	...	...
	3	180	35	5	25½	690,950	89.9	...	...	...	140	—.6	— 6	...	102	98	...	...
	4	195	40	6	26	696,530	93	...	...	...	135	—.6	—.6	...	102	90	84	64
	5	190	40	6	25½	701,970	90.6	...	...	...	152	—.6	—.6	...	104	105	100	64
	6	200	45	13	24½	707,523	92.5	...	...	...	130	—.6	—.6	...	102	102	92	62
	7	220	50	10	24½	713,339	96.9	...	...	...	135	—.6	—.6	...	102	105	90	62
	8	187	42	7	25	719,171	97.2	...	...	...	130	—.5	—.5	...	102	103	90	59
	8·30	190	40	7	25½	721,910	91.3	...	...	...	130	— 6	—.6	580	102	102	86	59
	9	200	43	8	25½	724,734	94.1	...	...	...	145	—.6	—.6	562	102	102	89	59
	9·30	210	46	8	25½	727,600	93.5	...	...	...	135	—.6	—.6	570	102	103	86	59
	10	197	45	8	25½	730,493	96 2	...	...	...	128	—.6	—.6	520	103	103	88	59
	10·30	180	40	7	25½	733.357	93 4	...	...	...	128	—.6	—.6	564	104	103	90	59
	11	197½	45	8	25½	736,235	95·9	...	...	...	130	—.6	—.6	560	103	101	89	59
	11·30	165	35½	5	26	739.048	93 7	...	...	...	130	—.6	—.6	608	102	102	90	59
	12	170	35	5	25½	741,718	89	...	...	...	125	—.6	—.6	580	104	103	85	59
Monday, June 9, 1902.	A. M.																	
	9	225	55	11	22	790,606	...	½	½	½	150	—.6	—.6	...	98	103	88	58
	9·30	210	52½	9	26	793.620	100.4	½	½	½	138	—.6	—.6	...	100	104	92	58
	10	200	48	8	25	796,557	97·9	½	½	½	135	—.6	—.6	...	98	98	90	59
	10·30	222½	55	11	24½	799 434	95 9	½	½	½	152	—.6	—.6	...	101	105	94	60
	11	210	55	9	26½	802,478	100.1	½	½	½	136	—.6	—.6	...	102	104	100	58
	11·30	187	47	8	25½	805,500	100.7	½	½	½	135	—.6	— 6	...	104	105	94	58
	12	222½	55	11	25½	808,477	99.2	½	½	½	126	—.6	—.6	...	103	107	94	58
	P. M.																	
	12·30	150	32	9½	27	811,238	92.3	½	...	½	135	—.4	— 4	...	107	96	90	60
	1	175	40	7	26	813,910	89	...	...	...	...	...	...	...	...	...	...	...
	2	170	40	7	25½	819,673	96	½	½	½	140	—.4	—.4	640	106	104	104	64
	3	215	52½	11	...	825,596	98.7	½	½	...	132	—.5	—.5	664	108	110	114	60
	4	215	50	10	...	831,642	100 7	c. f.	c. f.	c. f.	134	— 4	—.4	620	110	120	124	60
	8	215	55	11	25	850,144	...	½	½	c. f.	132	—.6	—.6	640	100	106	90	56
	8·30	220	55	11½	24	858,051	96.3	c. f.	½	c. f.	140	— 6	—.6	620	102	110	85	56
	9	211½	55	11	25	861,070	100.6	½	½	...	140	—.5	—.5	660	100	104	85	56
	9·30	222½	55	11½	24½	864,123	101.7	½	...	...	138	—.5	—.5	620	110	118	86	56
	10	215	52½	11	22	867,174	101.7	½	½	½	135	—.5	—.5	620	103	116	85	56
	10·30	210	52	10	26	870,184	100 3	½	½	½	128	—.6	—.6	600	102	104	84	56
	11	212½	52½	10	26½	873,229	101.5	½	½	½	120	—.6	—.6	628	98	100	84	56
	11·30	217½	55	11	26½	876,259	102	½	½	½	118	— 6	— 6	622	92	100	88	56
	12	220	55	11	26	879,351	102	½	½	½	118	—.6	—.6	631	98	104	95	56

* Coal very bad. c. f. = Cleaning fires.

REMARKS.

Sunday, June 8.—10 A. M.—Port fan engine turning 187 revolutions to keep furnace door liners cool. 11·30 A. M.—Slight head wind. 12 M.—Cleaning fires. 4 P. M.—Wind stronger. 5 P. M.—Wind rather strong. 6 P. M.—Good head wind. 8 P. M.—Fire doors open, cleaning fires. 10 P. M.—Slight head wind. 11·30 P. M.—Head wind dying out. 12 Night.—No head wind. Cleaning fires.

Monday, June 9.—9 A. M.—Two fan engines running. 12 M —Started to clean fires. 2 P. M.—No. 1 thermometer hung on level with fireman's head, front of port boiler. 3 P. M.—No. 2 thermometer hung on level with water tender's head, on first grating. 4 P. M.—No. 3 thermometer hung five feet from grating leading to deck. 4 P. M. to 8 P. M. watch, average 98.9 turns. No. 4 thermometer hung on deck in open air (atmospheric temperature). 8 P. M.—Location of No. 1 thermometer was where we got 200 degrees on way to San Diego. 10·30 P. M.—Slight head wind till about 11 P. M., when wind became stronger. 11 P. M.—Passed Cape Flattery about 11·30 P. M. 11·30 P. M.—Safety valve blowing off every few minutes in this watch.

blowers to draw from the upper part of the fire room above the after blowers. Heated air had banked up in this space in the early trials. Cast-iron cheek pieces, through which air is admitted, are also fitted at the sides of the furnace doors. The furnace fronts had previously badly overheated, but these cheek pieces have prevented this.

The engine-room log tables on opposite page show the great improvement that has been made in the fire rooms, and would seem to guarantee us against excessive temperatures in the fire rooms of the new naval vessels on which the Babcock and Wilcox boilers are to be used.

YACHTS.

New Turbine Yacht.—A very fast yacht, built to the order of Colonel McCalmont from designs prepared by Messrs. Cox & King, has lately been launched from the yard of Messrs. Yarrow & Co., Poplar. This yacht is of very special design, being built on the lines customary with vessels of the torpedo-boat class, and provided with turbine engines constructed by Messrs. Parsons, fitted with three shafts and three propellers on each shaft. As regards the hull and boilers, the yacht is identically similar to a first-class torpedo boat, the boilers being of the Yarrow type; therefore the trials will be watched with interest, as forming a fair comparison with those of similar vessels provided with boilers of this class but fitted with reciprocating engines, the machinery being the only portion of the vessel in which it differs from a Yarrow first-class torpedo boat.

Sir Christopher Furness.—This splendid yacht, which is to be propelled by turbine engines of the Parsons type, is now nearing the launching stage at the yard of Alexander Staphen & Sons, Linthouse. She will be the first to be launched of three pleasure yachts now under way in which Parsons turbine machinery is to be fitted.

BOOKS.

H. W. JOHNS-MANVILLE CO.—We are in receipt of the new "Catalog of Electrical Supplies" just issued by this company.

The new catalogue is much more complete than the last one issued by this firm, being supplied with a complete table of contents in the front and a comprehensive alphabetical index in the back, and contains 102 pages against 68 pages in the old one.

The new book, among other things of interest, gives a full line of overhead line materials and special moulded insulating pieces, together with many new articles, such as double trolley suspensions.

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